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ARMY COMBINED ARMS COMBAT DEVELOPMENTS ACTIVITY, FORT LEAVENWORTH, KANSAS

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Technical Report TR 11-76

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Technical Report TR 11-76
November 1976

Directorate of Combat Operations Analysis
US Army Combined Arms Combat Developments Activity
Fort Leavenworth, Kansas 66027

STATISTICAL ANALYSIS REPORT OF THE M60A1 CAMOUFLAGE TEST

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FOREWORD

I would like to express appreciation to Mr. Royce Hamlin and Ms. Sandra Elliott for their assistance in the compilation of this analysis report. Also a special thanks to Mrs. Rosalie Fulks for her conscientious and expert typing of this document.

ABSTRACT

Technical Report TR 11-76 utilizes data collected from the M60A1 camouflage test to determine the effect of camouflage applications on the ability of threat observers to detect/identify/acquire camouflaged and uncamouflaged M60A1 tanks. Camouflage effectiveness was assessed for static and dynamic tank targets in both day and nighttime environments. Other factors addressed in the test were test site (various vegetation/terrain conditions) and observer tactical approach mode (ground-foot patrol, wheeled vehicle, and tank vehicle; aerial-pop-up and reconnaissance route). Measures of performance analyzed are the time to target detection/identification/acquisition and the ranges at which these event times occurred.

EXECUTIVE SUMMARY

1. PURPOSE. The M60A1 camouflage test was conducted to generate data to perform a tactical assessment/military worth analysis of camouflage. Additionally, the data were utilized by the Countersurveillance Laboratory of the US Army Mobility Equipment Research and Development Center (USAMERDC) as input for their technical assessment of camouflage.

2. BACKGROUND. Headquarters, DARCOM, directed that the M60A1 be used as an example of what can be accomplished through the use of camouflage as a countersurveillance technique. The M60A1 tank, because of its strong signature, was chosen to provide a good representation of a specific area where camouflage may be successful. The US Army Tank-Automotive Command (TACOM) was responsible for specifying the camouflage materiel based on finalized TRADOC requirements. Test emphasis was directed toward reducing the visual and infrared signatures of the tank. The test was conducted by the Materiel Testing Directorate at Aberdeen Proving Ground (APG), Maryland, from 20 April to 11 August 1976.

3. OBJECTIVES.

a. Objective 1. To provide data on the time and range to detect, to recognize/identify, and to acquire the camouflaged and uncamouflaged M60A1 tank by trained observers using visual ground sensors.

b. Objective 2. To provide data on the time and range to detect and to recognize/identify the camouflaged and uncamouflaged M60A1 tank by trained aerial observers using the unaided eye (daytime) and night vision goggles (nighttime).

4. SCOPE OF EXPERIMENT.

a. Trained military observers employed ground and aerial surveillance tactics in an attempt to detect/identify/acquire camouflaged and uncamouflaged (pattern-painted) tank targets. Camouflage techniques included such devices as nets, brackets, and textured surfaces. The tank targets were deployed in both a static and a dynamic mode for the ground surveillance trials. All aerial surveillance observation were conducted against static tank targets. Day and night tests were conducted at various test sites, which were representative of distinct environments of vegetation/terrain conditions.

b. Ground surveillance trials commenced with the observers approaching the target array at specified ranges. The observers were afforded three modes of approach: foot patrol, wheeled vehicle, and

tank vehicle. Using various sighting devices, the observers were permitted search intervals at preselected positions along the approach route. The observers continued in their approach until both the tank targets were detected/identified/acquired. In the dynamic mode target trials, the observers occupied preselected static positions.

c. Day and night aerial surveillance trials utilized the OH-58 helicopter in both nap-of-the-earth route reconnaissance (RR) and pop-up (PU) flight tactics. Surveillance was conducted in accordance with FM 1-8, Aerial Observer Techniques and Procedures, July 1974. The RR routes and PU positions were premarked for each test trial.

5. TEST SHORTCOMINGS.

a. Adequate data on which to base a conclusive statement on the tactical assessment/military worth analysis of camouflage were not collected in the M60A1 camouflage test. Coordinated efforts of the test and analysis agencies from the beginning would have avoided the midunderstandings and deficiencies that arose from the test design plan. A detailed test design matrix depicting the total number of factor-level combinations (cells) and the number of replications per cell should have been explicitedly outlined. Such a matrix would have automatically identified the need to reduce the number of cells and increase the number of replications (i.e., a larger sample size increases the power of the statistical analysis). Additionally, past experience has shown the need to control search patterns during detection experiments. A control of the search pattern used would have eliminated or accounted for this source of variation (i.e., the reduction of experimental error variance through the identification of sources of variation that would otherwise be "pooled" within the error variance increases the power of the statistical analysis performed on the data).

b. Additionally, the necessity of maintaining firm control over all test trials cannot be overemphasized. The test officer must ensure that all test trials are executed according to the test design plan. The test should have been continuously monitored by an analyst with the authority to cease experimentation when test procedures were not executed as dictated by the test plan. Such an analyst would have been able to recognize and correct the error of the data collector in not recording the cumulative search times.

6. RESULTS.

a. <u>Detection</u>.

(1) Camouflage applications provided a tactical advantage to the camouflaged tank by degrading the detectability of the camouflaged

tank but only in the day/stationary target mode trials for both the ground and aerial surveillance test.

(2) In the day/dynamic target mode posture, the dust signature and noise cue produced by the tank targets completely nullified the effect of camouflage.

(3) The effect of camouflage was completely diminished in the night/stationary target mode scenario for both the ground and aerial surveillance test. The limited visibility hindered the visual acuity and discrimination ability of the observers; as a result, both tank targets were especially difficult to detect.

(4) In the night/dynamic target mode test scenario the effectiveness of camouflage was nullified by a combination of opposing effects. The effect of limited visibility in the nighttime environment reduced the detectability of the tank targets; simultaneously, the noise effect produced by the tanks aided detection.

b. Identification. The identification of the pattern-painted tank was performed in a more timely manner than the identification of the camouflaged tank, but only in the day/stationary target mode trials.

(1) It was generally determined that a high power sighting device afforded the observers a timely acquisition capability against a static tank target.

(2) Moving tank targets dictated the necessity of keeping the targets within the field of view of the sighting device a sufficient length of time for acquisition; sighting devices that had an appropriate combination of a wide field of view and relatively high power afforded the observers the best acquisition capability.

c. Acquisition. Camouflage applications, in general, did not affect the observers' acquisition of the camouflaged tank (i.e., acquisition times for the pattern-painted and camouflaged tanks were not significantly different).

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1. INTRODUCTION.

a. Purpose. This analysis was performed to analyze the data collected from the M60A1 Camouflage Test and to make a tactical assessment of camouflage within the context of the test scenario. The measures of performance analyzed in this report are the time to detection/identification/acquisition of the M60A1 tanks by threat observers and the ranges at which these event times occurred. This report is one of two technical reports published by CACDA that are substantive in nature, the other being a report of the BLDM model analysis. The comprehensive and final product of the evaluation and assessment of camouflage, however, will be compiled and published by the USAMERDC and USACACDA. This consolidation effort will also incorporate the report published by the test agency, TECOM.

b. Objectives. The two objectives to this analysis are as follows:

(1) Compare the effects of various camouflage applications to the M60A1 tank with a standard pattern-painted M60A1 tank on the ability of threat observers employing various sighting devices to detect/identify/acquire each tank.

(2) Provide input into the Battalion Level Differential Model (BLDM) to perform the military worth analysis of camouflage (the results of which are to be published under separate cover). Military worth as defined in this M60A1 camouflage test program is the effect of a particular attribute or factor (such as acquisition) on the expected outcome of a military engagement.

2. BACKGROUND.

a. Scope. Testing was conducted by the Materiel Testing Directorate at Aberdeen Proving Ground (APG) during the period 20 April to 11 August 1976. A camouflaged test tank was compared with a standard pattern-painted M60A1 control tank throughout the test. Military observers employing ground and aerial surveillance tactics attempted to detect/identify/acquire tank targets within a target array composed of tanks and distractors (e.g., APCs, MICV). The ground test trials afforded the observers three approach modes: foot patrol, wheeled vehicle, and tank vehicle. An OH-58 helicopter was used for the aerial surveillance trials. Observers were trained in the detection and recognition/identification of targets and were also familiar with the sighting devices to be used. TRADOC requested that specific visual and visual-aided sighting devices be used for testing camouflage effectiveness.

(1) Test site conditions used in this test were as follows:

(a) Terrain (flat and rolling).

(b) Vegetation (light and heavy).

(c) Range (1, 2, and 3 kilometers).

(d) Visibility (clear to limited).

(e) Time (day and night).

(f) Tactical mode of target (dynamic and static).

(2) The camouflage and applications addressed are identified as follows:

(a) Brackets, nets, and disrupters.

(b) Pattern-painting with countershading.

(c) Antenna camouflage.

(d) Textured surfaces.

(e) Interior light filters.

(f) Exhaust deflector.

(g) Personnel heater shield.

(h) Fender skirts.

(i) Road wheel covers.

(j) Light shrouds.

(3) The eight visual and visual-aided sighting devices used in the ground surveillance test are as follows:

(a) Unaided eye.

(b) 7x50mm binocular.

(c) TOW sight.

(d) M47 DRAGON sight.

(e) M32/35E1 tank periscope.

(f) M105D tank telescope.

(g) AN/TVS-5 night vision sight (used on a M67 90mm recoilless rifle).

(h) AN/PVS-4 night vision sight (used on a M203 grenade launcher rifle).

(4) The visual and visual-aided sighting devices used in the aerial surveillance test are as follows:

(a) Unaided eye.

(b) AN/PVS-5 night vision goggles.

b. Measures of Performance. The measures of performance (MOP) addressed in this report are listed below.

(1) The time and range to detection of the camouflaged and pattern-painted M60A1 tank by trained observers and/or interpreters using visual and IR sensors.

(2) The probability of detection, by trained observers and/or interpreters, of the camouflaged and pattern-painted M60A1 tank as a function of time and range against visual and IR sensors.

(3) The time and range to identification of the camouflaged and pattern-painted M60A1 tanks, by trained observers and/or interpreters, using visual and IR sensors.

(4) The probability of identification of the camouflaged and pattern-painted M60A1 tanks, by trained observers and/or interpreters, against visual and IR sensors as a function of time and range.

(5) The time and range to acquisition of the camouflaged and pattern-painted M60A1 tanks, by trained observers, using visual and IR sensors (ground surveillance trials only).

(6) The probability of acquisition of the camouflaged and pattern-painted M60A1 tanks, by trained observers and/or interpreters, as a function of time and range against visual and IR sensors (ground surveillance trials only).

c. Definition of Terms. The following terms are defined as they were used in this test:

(1) Target detection - the observation of a potential military target which might be a tank.

(2) Target recognition/identification - the recognition of a detected target as an identifiable item such as a tank, an APC, a self-propelled gun, or a truck.

(3) Target acquisition - the sighting and final lay of a target with a weapon sight.

d. Test Description.

(1) Ground surveillance.

(a) The test tank (henceforth referred to as the camouflaged (CAM) test tank) and the test control tank (henceforth referred to as the pattern-painted (PP) control tank), along with other pattern-painted distractors (such as APCs, MICVs, and/or self-propelled guns), were counterbalanced in at least two target arrays within a 60° search sector for all trials. Test and control tanks occupied preselected locations for each test trial. The CAM and PP tanks occupied each target position an equal number of times for each test site. The PP control tank and other distractors used in the visual observation fan were pattern-painted in accordance with TB-200. Preliminary to start of the scheduled test trials, daytime comparison runs were made against a PP control tank and an olive-drab colored tank. Only the PP control was utilized in the subsequent test runs with the CAM test tank.

(b) In the static target trials, an observer team (consisting of one primary observer and one secondary observer) began its approach from a specified maximum range. The primary observer attempted to detect the tank targets, with the designated sighting device, during search periods along the approach route. Search times by the primary observer were limited to a maximum duration of 1 minute. If a target was not detected during the 1-minute search, the observer broke visual contact with the sighting device, the observer team continued in its approach by moving approximately 100 meters along the approach route, and the primary observer resumed search with his sighting device. Once the primary observer detected/identified a tank target, he "handed off" the target to the secondary observer who then attempted to acquire the target with a different sighting device. The observer team continued in its approach until both tank targets were detected/identified/acquired. Some devices required observers to be static (whether the test tank was static or dynamic); all observations of dynamic targets were made by stationary observers from preselected observation posts. During dynamic target trials, target tanks made intermittent stops. Moving distractors were also used in dynamic target trials. Approach speeds for moving observer teams against static targets did not exceed 7 miles per hour. Target acquisition with the

tank gun commenced with the gun parallel to the direction of travel so as to establish the angle of deflection marked by the final lay of the weapon.

(c) All observers were required to have 20/20 corrected visual acuity; color vision of each participant was noted. Vision and perception tests were administered prior to the start of the testing schedule. Preliminary to any active test trials, observers were fully briefed to look for tanks as targets of interest; to detect, recognize/identify, and acquire both the CAM test tank and the PP control tank; and not to acquire any other target noted (even though detection and identification of distractors or nontanks had been made).

(2) Aerial surveillance.

(a) Test sites used were from the same areas as those utilized in the ground observation tests. Surveillance was conducted in accordance with FM 1-8, Aerial Observer Techniques and Procedures, July 1974. A low performance aircraft (LOH-58 helicopter) was utilized in both nap-of-the-earth route reconnaissance (RR) and pop-up (PU) flight modes in accordance with current tactical practice of the air cavalry.

(b) Ten qualified US Army pilots were used as aerial observers. Both the CAM test tank and the PP control tank were deployed in the static mode only in simulated tactical configurations as dictated by flat to rolling terrain with light to heavy vegetation. Observations were made under conditions of clear visibility both day and night. Trials utilized eye-movement instrumentation for objective measurement of single glance duration times, single glance field of view, and maximum dwell time. The observer used the eye-mark system, which was connected via fiber optics to both a DBM-4C slow speed camera and to a Sony (videotape) TV recorder. A second DBM-4C camera was mounted on the helicopter using a Human Engineering Laboratory (HEL) mounting system. Both DBM-4C cameras operated from the same control box. When the observer announced that he sighted the target, he depressed the "pickle switch" which marked the frame in both cameras, thereby providing a scoring mark for the eye point of regard and for the position of the aircraft with regard to the test course (search direction with regard to flight path). Pop-up positions were premarked and slant range to target predetermined. Phase lines were layed out along the course perpendicular to the aircraft path to establish slant range upon target detection and/or target recognition/identification. All helicopter radio transmissions were recorded. The cameras operated

six frames per second, using ultraviolet (UV) sensitive film to facilitate data collection by pinpointing the target of interest and its UV beacon.

e. Description of Test Data.

(1) Ground surveillance data. The initial data received by the Combat Operations Analysis Directorate (COAD) consisted of individual finalized data sheets composed of range and time data recorded during each trial execution of the ground surveillance trials. In addition, summary sheets of the range and time data in a much more usable form were forwarded to COAD. The range data consisted of the range of tank target detection/identification/acquisition. The time data consisted of the time to detect/identify/acquire each target from the time the observer began search at the detection/identification/acquisition range; i.e., the times reflected only those instances in which a detection was made. If no detection was made, the 60-second elapsed time was not recorded by the data collector. Since these times did not reflect the total time the observer attempted to detect/identify/acquire each target from trial start, a request was made to have the Materials Testing Directorate forward the total cumulative search times for all test trials. Cumulative times were provided for all trials except for the groups 10 and 12 (identified in table 1). Ranges of detection/identification/acquisition computed from the cumulative time data, using the 100-meter advance/1-minute search test procedure, were not the same as those ranges contained in the summary sheets. Therefore, an independent analysis was performed on the range and time data. However, because the range data exhibited a greater degree of consistency than the time data, emphasis should be placed on the analysis results of the range data.

(a) Table 1 correlates the test conditions of the ground surveillance trials with the groups of data that were forwarded to COAD.

(b) Table 2 is a matrix of all the test trials conducted identified by the factors target mode, time of day, and trial start range (maximum range).

(2) Aerial surveillance data. These data were forwarded to COAD as requested and in summary form. Table 3 depicts the identification codes for the aerial surveillance data forwarded to COAD.

Table 1. Ground surveillance identification codes of test trials

	Vegetation	Terrain	Visibility	Maximum Range	Target Mode	Day or Night	Test Site
Group 1	L	F	8	3	S	D	R,Q
2	H	R	8	2	D	D	X
3	L	R	7/8	2	S	D	T
4	L	R	*[a]	3	S	N	U
5	L	F	8	2	D	D	S
6	H	R	*[a]	2	S	N	V
7	H	R	*[a]	1	D	N	W
8	L	R	*[a]	2	S	N	U,V
9[b]	L	R	*[a]	3	S	D	Y
10	L	R	7	3	S	D	Y
11	H	R	7	2	D	D	Y
12[c]	H	R	7	2	S	D	P

Vegetation: L-light, H-heavy

Terrain: F-flat, R-rolling

Visibility: miles

Maximum range: kilometers

Target mode: S-static, D-dynamic

Day or Night: D-day, N-night

[a] Visibility varied from trial to trial.

[b] Simulated tactical trials (static mode). These data were not analyzed because the validity and usability of the data were considered highly suspect by the test officer.

[c] Baseline trials comparing the pattern-painted tank with the olive-drab colored tank.

Table 2. Matrix of target mode test conditions

Maximum Range (meters)	Target Mode			
	Stationary		Moving	
	Day	Night	Day	Night
3,000	10[a]- Light/Rolling 1 - Light/Flat	4- Light/Rolling		
2,000	3- Light/Rolling 12[b]- Heavy/Rolling	8- Light/Rolling 6- Heavy/Rolling	5- Light/Flat 2- Heavy/Rolling 11- Heavy/Rolling	
1,000				7- Heavy/Rolling

[a] Data group number - vegetation/terrain condition.
[b] Baseline trials.

Table 3. Aerial surveillance identification codes of test trials*

Flight Mode	Vegetation	Terrain	Visibility	Maximum Range	Target Mode	Day or Night	Test Site
Pop-up Route Reconnaissance	L	F	4	1	S	D	A
Pop-up Route Reconnaissance	L	F	1	1	S	N	A

* Code markings are identical to those used in table 1, Ground surveillance identification codes of test trials.

f. Military Worth Analysis. The Battalion Level Differential Model (BLDM) was the model selected to be used in the assessment of the military worth of camouflage. The model plays a day scenario with a static Blue force defending against an attacking Red force. The required inputs into the model must be in the form of acquisition rates for each tank target, per 500-meter bands, for similar vegetation/terrain conditions and ranges in both a static and a dynamic mode. Data from groups 1 and 5 (see table 2) were selected because they were the only data that could satisfy these input requirements. The acquisition rates were calculated based on the times/ranges associated with the first target detected. These data reflect the initial acquisition of a nonfiring stationary target (group 1 data) and a nonfiring moving target (group 5 data).

3. METHODOLOGY.

a. Description. The M60A1 test resulted in, for the most part, an unbalanced and sparsely distributed frequency of trials as depicted in table 4. Pooling of the data across the factors target array and approach mode was necessary in order to obtain an overall and consistent assessment of the effect of camouflage on the measures of performance (MOP). The test trials were classified into nine groupings with trials within each group being conducted under the same vegetation/terrain conditions and the same maximum range.

b. Extent of Analysis.

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Table 4. M60A1 camouflage test design matrix (ground surveillance test trials)

		DAY/STATIONARY											DAY/MOVING										NIGHT/STATIONARY										
		VEGETATION/TERRAIN											VEGETATION/TERRAIN										VEGETATION/TERRAIN							VEGETATION/TERRAIN		VEGETATION/TERRAIN	
		LIGHT/FLAT					LIGHT/ROLLING						LIGHT/FLAT				HEAVY/ROLLING						LIGHT/ROLLING							HEAVY/ROLLING		HEAVY/ROLLING	
		MAXIMUM RANGE (M)					MAXIMUM RANGE (M)						MAXIMUM RANGE (M)				MAXIMUM RANGE (M)						MAXIMUM RANGE (M)			MAXIMUM RANGE (M)				MAX RANGE (M)		MAX RANGE (M)	
		3,000					2,000				3,000		2,000				2,000						2,000			3,000				2,000		1,000	
		TEST SITE					TEST SITE				TEST SITE		TEST SITE				TEST SITE						TEST SITE			TEST SITE				TEST SITE		TEST SITE	
		R		Q			T				Y		S				X				Y		U		V	U				V		W	
APPROACH MODE	SIGHTING DEVICE	TARGET ARRAY		TARGET ARRAY			TARGET ARRAY				TARGET ARRAY		TARGET ARRAY				TARGET ARRAY				TARGET ARRAY		TARGET ARRAY		TARGET ARRAY	TARGET ARRAY				TARGET ARRAY		TARGET ARRAY	
		1	2	1	2	3	1	2	3	4	1	2	1	2	3	4	1	2	3	4	1	2	1	2	1	1	2	3	4	1	2	1	2
GROUND	UNAIDED			4	4	1			5	4			1		4	6	5	5	3	4						6	4	4	8				
	BINOCULAR	6	4				5	5			5	5	4	5			5	5	2	1	5	4	5	5						5	5	5	5
	TOW														5	5																	
	DRAGON			4	4	1			5	6																							
	PERISCOPE																																
	TELESCOPE																																
	NVD(RR)																																
	NVD(GL)																						5	10	9	6				5	5	5	5
WHEELED VEHICLE	UNAIDED			6	6				5	5					5																		
	BINOCULAR	6	5				5	5			5	5	5	5			5	5	5	5						6		3	8				
	TOW				6	4			5	5					5	5					5	4	5	10	9	7				5	5	5	5
	DRAGON																																
	PERISCOPE																																
	TELESCOPE																																
	NVD(RR)																						5	5						5	5	5	5
	NVD(GL)																																
TANK	UNAIDED																					1											
	BINOCULAR	5	5				5	5			5	5	5	5			5	5	4	1	5	4											
	TOW																																
	DRAGON																																
	PERISCOPE	5	5						5	5					5	5			1	3			5	5	9	6		2	6	5	5	5	5
	TELESCOPE																																
	NVD(RR)																																
	NVD(GL)																							5									

(1) Range data.

(a) The Kolmogorov-Smirnov two-sample test was performed on the pooled CAM and PP range data per group. This test was performed to test the hypothesis that the distribution of CAM and PP range data were from two identically distributed parent populations. This hypothesis is equivalent to saying that the ranges of detection/identification/acquisition for the CAM and PP tank are equal; i.e., camouflage equipment does not significantly reduce the range of detection/identification/acquisition when compared to the detection/identification/acquisition range of the PP tank. The specified alternate hypothesis states that the distribution of detection/identification/acquisition range for the CAM tank is less than the detection/identification/acquisition range for the PP tank; i.e., camouflage equipment significantly reduces the detection/identification/acquisition range of a CAM tank in comparison to the detection/identification/acquisition range of a PP tank. (This and all subsequent tests were conducted with an α-level of .10.)

(b) Additionally, a two-factor analysis of variance (ANOVA) was performed on the detection range with the factors tank type and sighting device. This analysis was performed on the raw data when the assumptions of normality and homogeniety were satisfied. If the assumptions could not be appreciably satisfied, a transformation of the data was performed. ANOVA was used to test the hypothesis that the mean detection ranges for the device types are equal and that the mean detection ranges for each tank type are equal. If this hypothesis is rejected; i.e., means not equal, t-tests among the factor levels were conducted to determine which means were significantly different.

(c) Distribution analysis was performed on the data using the Kolmogorov-Smirnov (K-S) one-sample test. A K-S one-sample test determines which one of three theoretical distributions (normal, lognormal, or exponential) best describes the distribution form of the empirical data. The normal distribution is characterized by the mean and standard deviation, $\overline{x}$ and s, respectively. The lognormal distribution as used in this report is characterized by the calculated median (x_0) and gamma (γ). See appendix A for a detailed discussion of this distribution. The exponential distribution is characterized by a single parameter, the mean.

(2) Time data.

(a) The probability of detecting the CAM or PP tank first was calculated and distribution analysis was performed on the time data. A two-factor ANOVA (tank x sighting device) was performed on the first detection times. This analysis was performed on the raw data when the assumptions of normality and homogeniety were satisfied. If the

assumptions could not be appreciably satisfied, a transformation of the data was performed. This statistical test tests the hypothesis that the mean time of the first target detected for each of the sighting devices is equal and that the mean detection time for tank type is equal. If this hypothesis is rejected, t-tests among factor levels were conducted to determine which means were significantly different.

(b) A two-factor ANOVA was performed on the acquisition times for all trials (inherent in this time is the hand-off time) with the factors tank type and sighting device. This analysis tests the hypothesis of equal mean acquisition times for each device type and tank type tested.

(c) Distribution analysis was performed on the data after the above statistical tests were completed.

(d) The results of distribution analysis performed on the individual detection/identification/acquisition data are contained in appendix B. This analysis was performed independent of the analysis presented in the main body of the report. The rationale for the independent analyses was to analyze the detection/identification/acquisition data of only those trials in which the entire acquisition sequence was performed (i.e., all unaided-visual detection data were deleted from this analysis). The comparison of the detection/identification/acquisition times is most meaningful when the identical test conditions/personnel, and hence sample size, are maintained throughout the acquisition sequence.

4. RESULTS. The statistical results of the analyses performed on the test data are presented by data group, according to the classification of each group within the four categories of day/stationary, day/moving, night/stationary, and night/moving target modes (for the ground surveillance test.) A description of the vegetation/terrain conditions and maximum range of trial start is provided for each of the data groups. The aerial test results are presented for each of the flight modes per day/night test trials.

a. <u>Ground Surveillance</u>.

(1) Day/stationary target mode trials.

(a) Group 12 (baseline test trials) - light vegetation/rolling terrain conditions; 2 kilometers maximum range (range of trial start). (See table 5 for the matrix of test trials.)

<u>1</u>. Subsequent to pooling the detection ranges for each tank across approach mode, target array, and sighting device, the olive-drab (OD) tank data were determined to follow a lognormal

Table 5. Matrix of group 12 baseline day trials - static target mode; heavy vegetation/rolling terrain conditions; 2 kilometers maximum range

Approach Mode	Detection, Identification/ Acquisition Device	Test Site P: Target Array 1	Test Site P: Target Array 2
Ground	Unaided/DRAGON	5*	5
	Binocular		
	TOW		
	DRAGON		
	Periscope		
Wheeled Vehicle	Unaided		
	Binocular/TOW	5	5
	TOW		
	DRAGON		
	Periscope		
Tank	Unaided		
	Binocular		
	TOW		
	DRAGON		
	Periscope/Tele	5	5

* Replications per cell.

distribution; whereas the PP tank range data were best described as normal. The OD tank range data were not significantly less than the PP tank ranges. (See figure 1 for the cumulative distribution function (CDF) plots of the data and distribution parameters.)

2. Performing a 2x3 (tank x device) analysis of variance (ANOVA) on the detection ranges resulted in the significance of the factor device type. Subsequent t-tests among the three levels of device type identified a significant difference between the binocular, unaided, and periscope sighting devices. The binocular device afforded the observers the capability of detecting the tank targets at the furthest observer-to-target ranges. The unaided visual technique proved second best, with the periscope affording the observers the poorest detection capability. Figure 2 depicts the CDFs and distribution parameters of the data.

(b) Group 1 - light vegetation/flat terrain conditions; 3 kilometers maximum range. (See table 6 for the matrix of test trials.)

1. After pooling the detection ranges across test site, approach mode, target array, and sighting device, it was determined that the CAM tank was detected at significantly shorter observer-to-target ranges than the PP tank. This difference was the result of the camouflaged applications, which blended the CAM tank into the immediate surroundings and made the detection of the CAM tank difficult at longer ranges. (Figure 3 depicts the CDFs of the range data and the distribution parameters.) The observer's difficulty in detecting the CAM tank was also reflected in the probability of the first tank target detected. The CAM tank was detected first in 18 percent of the trials, with a mean time to detection of 8.1 minutes. In the other 82 percent of the trials, the PP tank was detected first, with a mean detection time of 9.2 minutes (1.1 minute more than the mean detection time of the CAM tank). This difference may be attributable to a possible "cue phenomenon," natural or artificial, which singled out the CAM tank to the observers in 18 percent of the trials; e.g., location of CAM tank with respect to the PP tank or camouflage applications that aided the detection of the CAM tank. (See figure 4 for the distribution parameters of the data and a cumulative plot of observer times based upon the percentage of first detections.)

2. A 2x5 ANOVA (tank x device) on the detection range data resulted in the significance of each of the main factors and the interaction. Figure 5 depicts a plot of each of the 10 factor-level mean detection ranges for each tank target per sighting device. There appears to be a constant difference between the mean detection ranges of the CAM and PP tank for all device types, except for the binocular device. Observers using binoculars recorded the highest mean detection

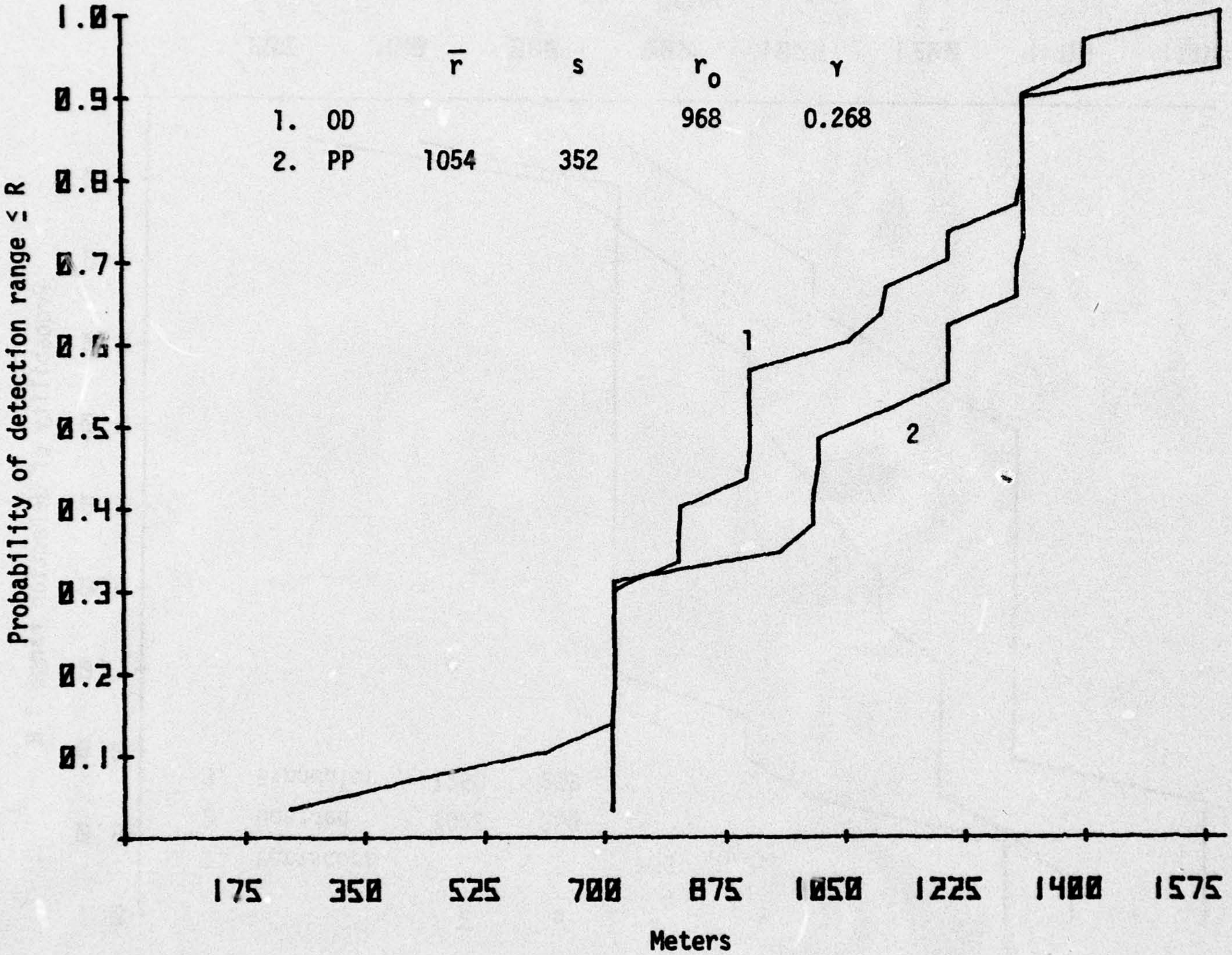

Figure 1. Cumulative distribution of detection range per tank target type, group 12 baseline data

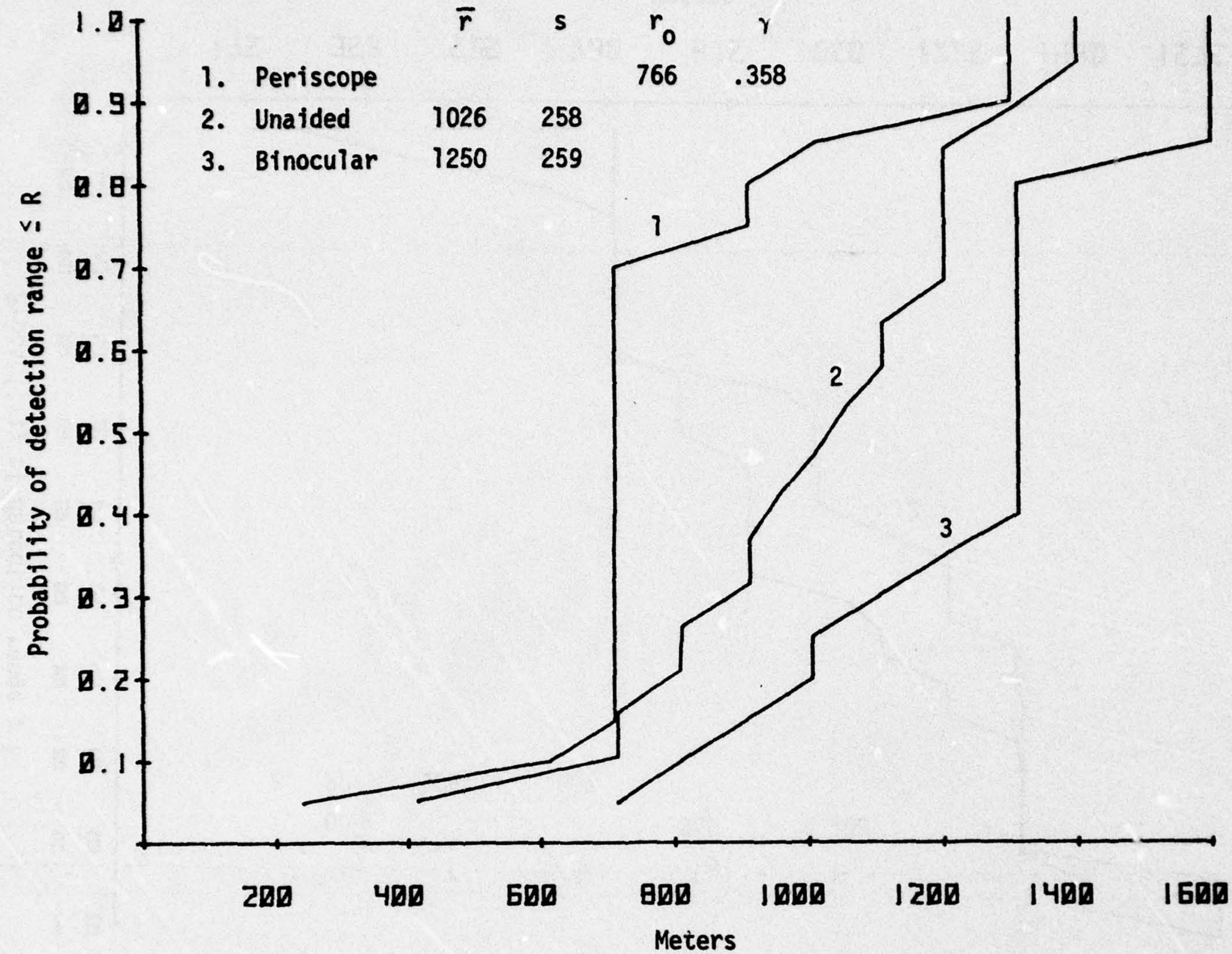

Figure 2. Cumulative distribution of detection range per device type, group 12 baseline data

Table 6. Matrix of group 1 day trials - static target mode; light vegetation/flat terrain conditions; 3 kilometers maximum range

		Test Site					
		R			Q		
Approach Mode	Detection, Identification/ Acquisition Device	Target Array			Target Array		
		1	2	3	1	2	3
Ground	Unaided/---[a]				5[c]	4	1
	Binocular/DRAGON	6	4				
	TOW						
	DRAGON/DRAGON[b]				4	4	1
	Periscope						
Wheeled Vehicle	Unaided/---[a]				6	6	
	Binocular/TOW	6	5				
	TOW/TOW[b]					6	4
	DRAGON						
	Periscope						
Tank	Unaided						
	Binocular/Peri	5	5				
	TOW						
	DRAGON						
	Periscope/Tele				5	5	

[a] Acquisition was not performed for these trials.

[b] Range data were not supplied for these acquisition trials.

[c] Replications per cell.

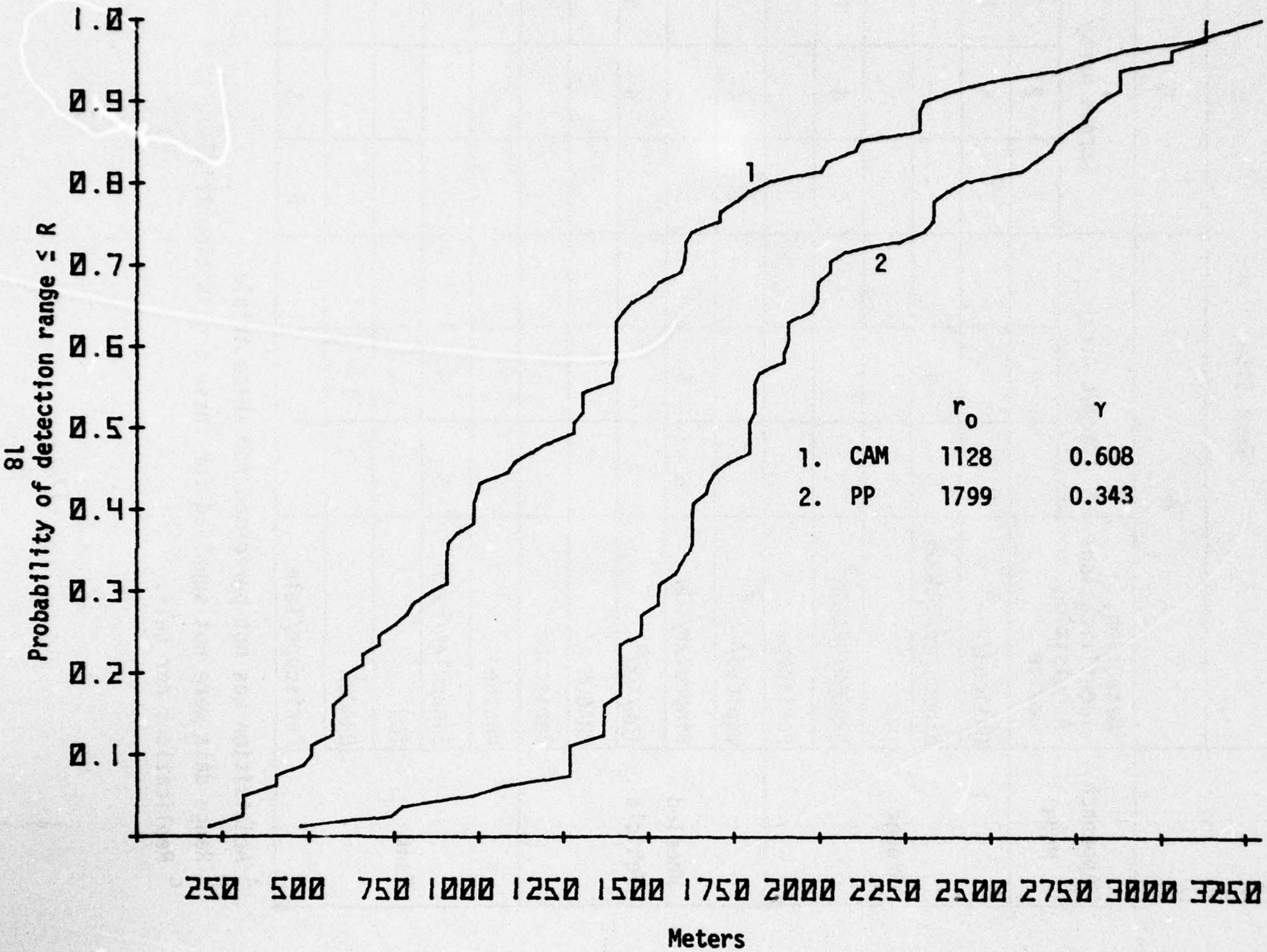

Figure 3. Cumulative distribution of detection range per tank target type, group 1 data

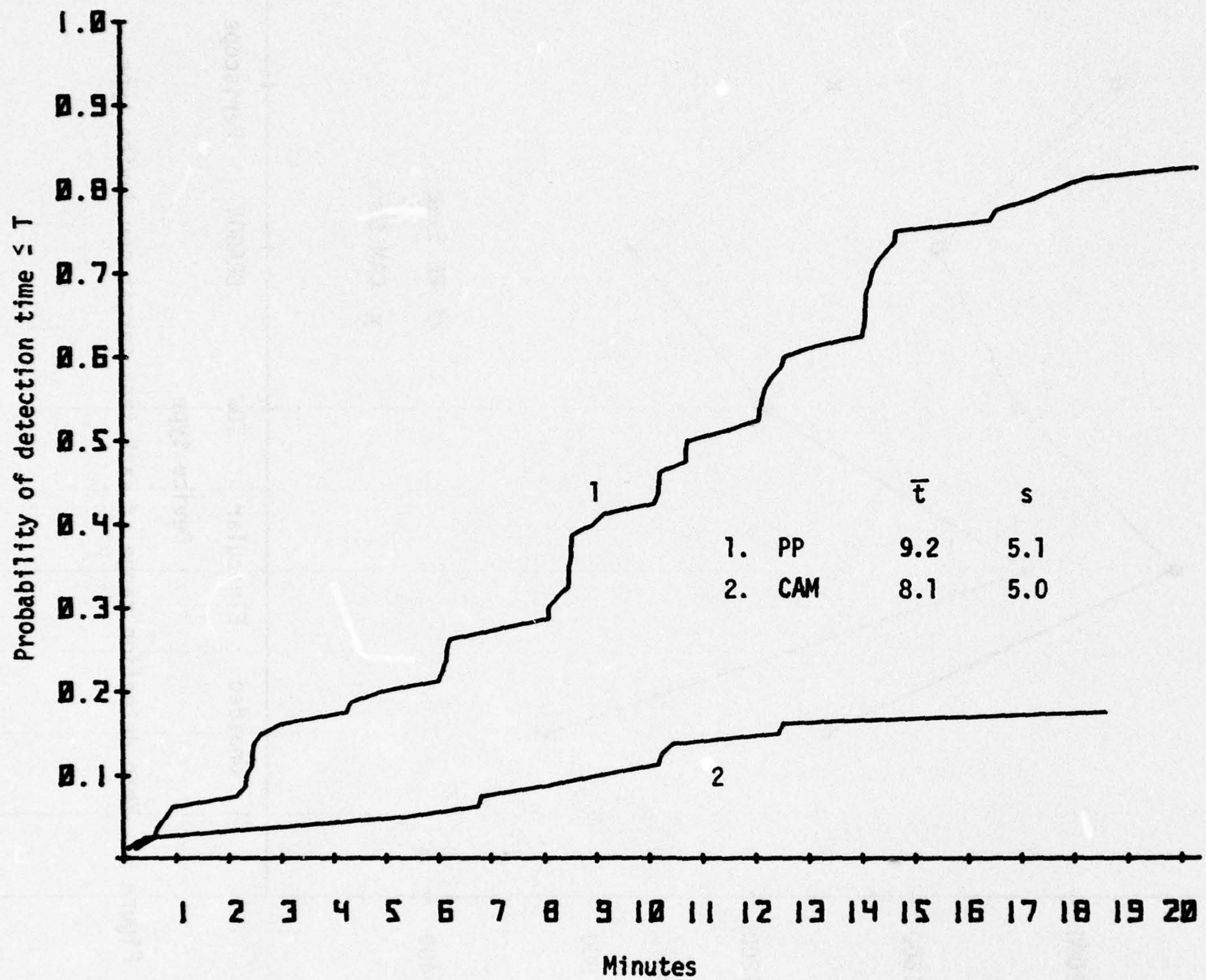

Figure 4. Cumulative distribution of time to first detection per tank target type, group 1 data

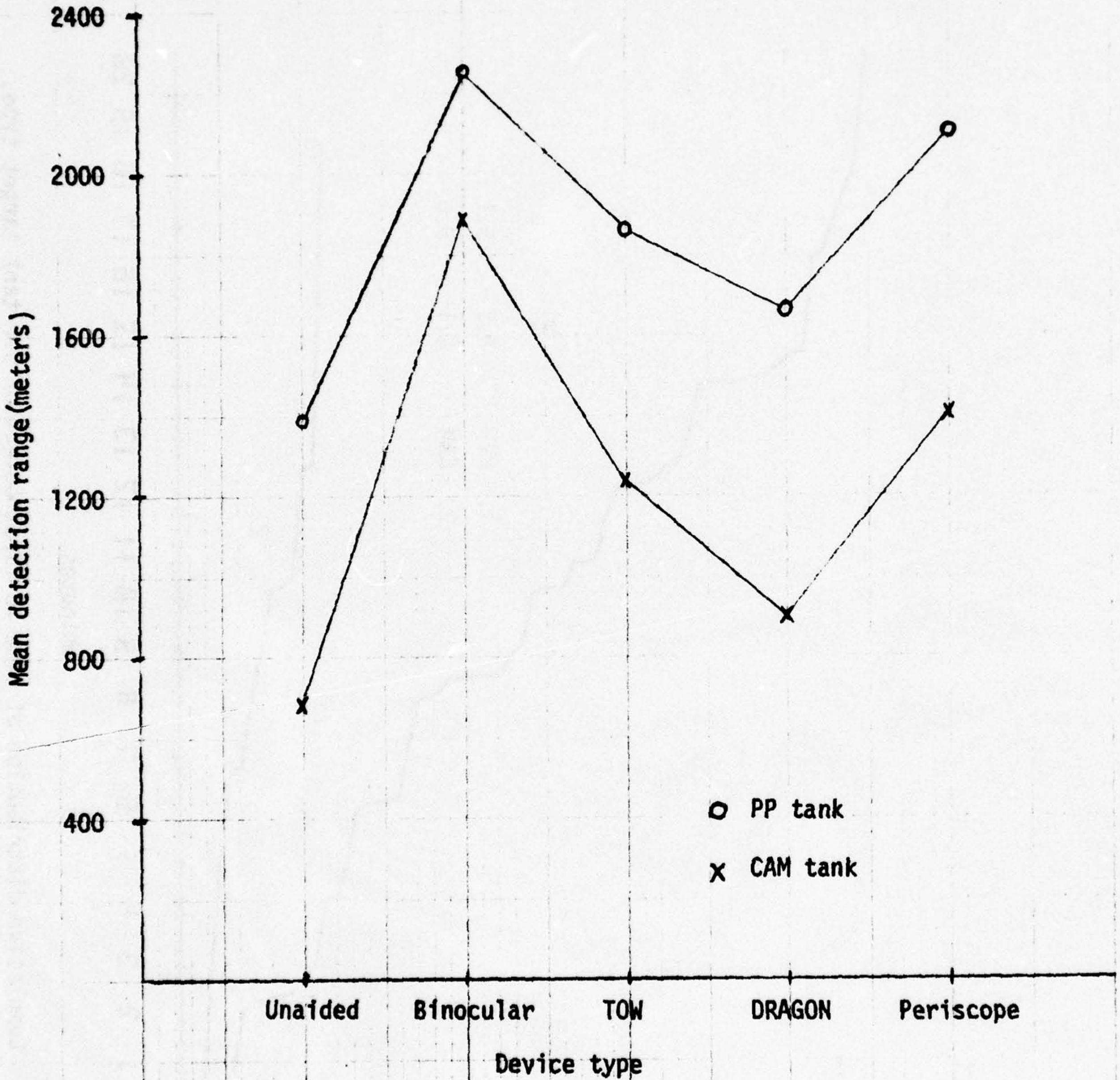

Figure 5. Mean detection range of each tank target per device type

range for each of the tank targets. This result may indicate a logical finding; that is, a device that has a wide field of view (FOV) and is high powered as well affords the observer the "best" detection capability.

3. A 2x5 ANOVA on the first detection times resulted in the significance of the main effects, tank and device type. T-tests among the five levels of device type identified a significant difference between the following groups of devices: (1) binocular, TOW, and tank periscope, and (2) unaided and DRAGON sighting devices. The binocular, TOW, and periscope sighting devices afforded the observers the best detection capability. This result may be due to the higher magnification of the binocular and TOW sight in relationship to the unaided and DRAGON sights. It is not known why the periscope performed better than the DRAGON sight; a possibility is that the relatively low power/wide FOV of the periscope may possess a better detection capability than the high power/narrow FOV of the DRAGON sight. (The distribution parameters and cumulative distribution function (CDF) of the data are depicted in figure 6.)

4. An ANOVA on acquisition times resulted in the significance of the main effect, device type. Subsequent tests revealed the existence of significant differences between the TOW, DRAGON, and tank sighting devices; i.e., the periscope and telescope performed equally well. Observers were able to acquire the tank targets in the most timely manner when they used the TOW sight. This result is reasonable because the TOW has the highest power (13x) of all sighting devices used in this test. The DRAGON sight required the next least amount of time, with the periscope and telescope sights requiring the most amount of time. Figure 7 depicts the CDF of these data and the distribution parameters.

(c) Group 3 - light vegetation/rolling terrain conditions; 2 kilometers maximum range. (See table 7 for the matrix of test trials.)

1. The pooled CAM detection ranges were found to be normally distributed with a mean of 1,168 meters and a standard deviation of 462 meters. These ranges were determined to be significantly less than the PP ranges, which were best described as lognormal with a median range of 1,576 meters and a gamma of .321. This difference in ranges was the result of the camouflage applications affixed to the CAM tank, which reduced the detectability of the tank. (Figure 8 depicts the CDF and distribution parameters of the range data.) The effect of camouflage was also reflected in the probability and time to the first target detected. The PP and CAM detection times were found to be lognormally distributed, with the PP tank being detected first in 80 percent of the test trials (probability of detecting the CAM tank first was .20). The CAM tank had a median time to detection of 5.7 minutes as compared to the PP tank with a median detection time of 2.7 minutes. Figure 9 depicts the distribution parameters of the time data and a

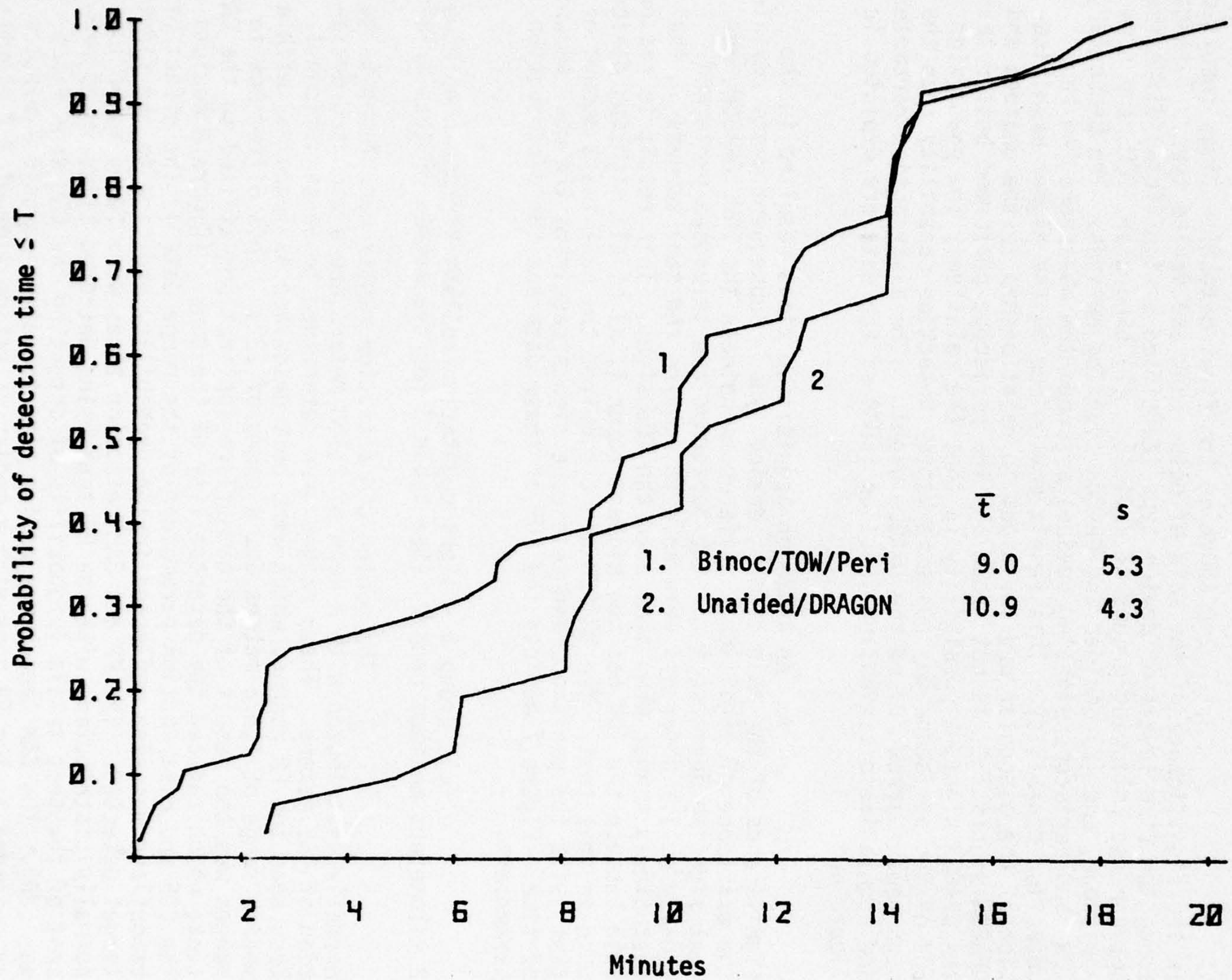

Figure 6. Cumulative distribution of time to first detection per device type, group 1 data

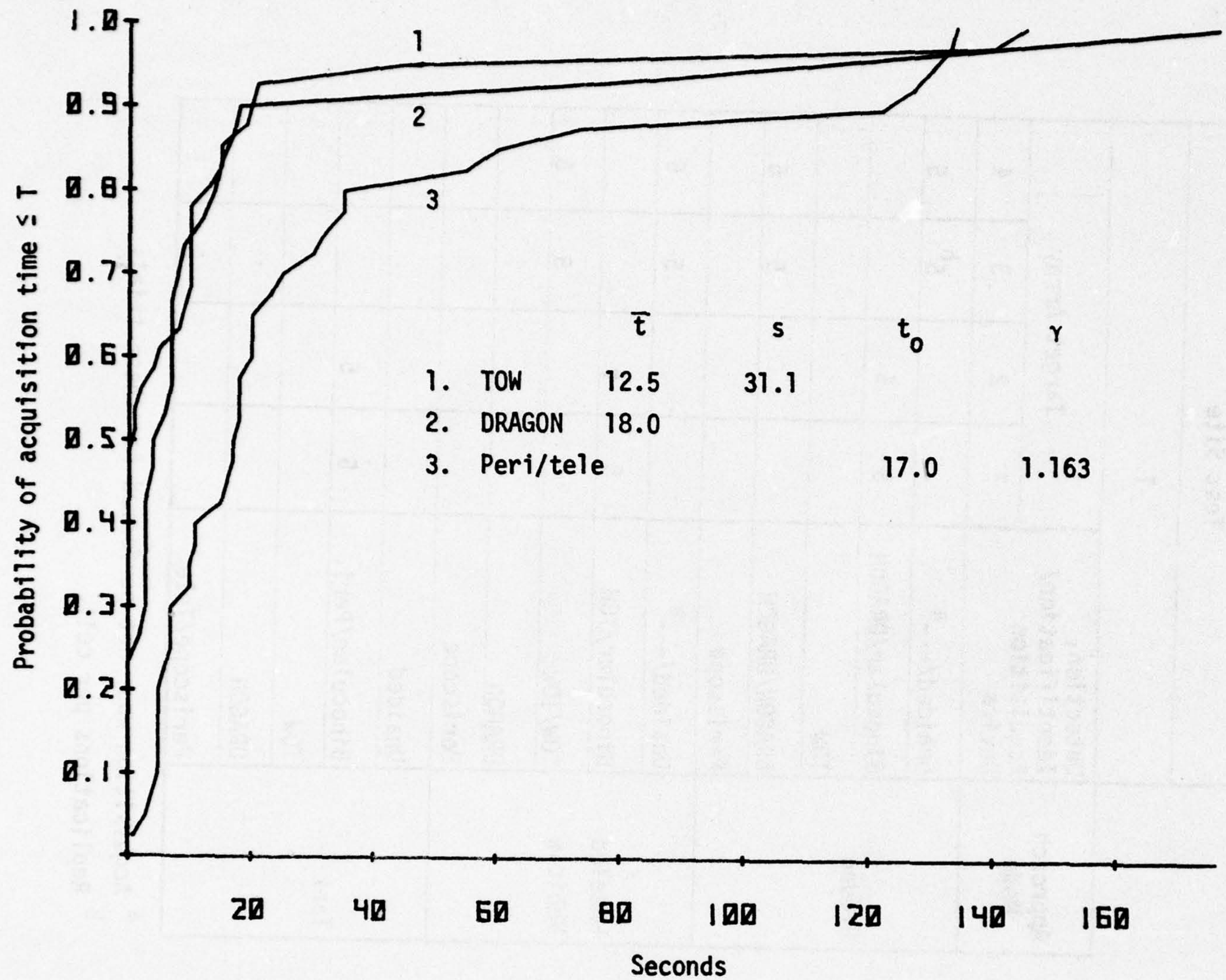

Figure 7. Cumulative distribution of acquisition time per device type, group 1 data

Table 7. Matrix of group 3 day trials - static target mode; light vegetation/rolling terrain conditions; 2 kilometers maximum range

Approach Mode	Detection, Identification/ Acquisition Device	Test Site T: Target Array 1	2	3	4
Ground	Unaided/---[a]			5[b]	5
	Binocular/DRAGON	5	5		
	TOW				
	DRAGON/DRAGON			5	5
	Periscope				
Wheeled Vehicle	Unaided/---[a]			5	5
	Binocular/TOW	5	5		
	TOW/TOW			5	5
	DRAGON				
	Periscope				
Tank	Unaided				
	Binocular/Peri.	5	5		
	TOW				
	DRAGON				
	Periscope/Tele.			5	5

[a] Acquisition was not performed for these trials.

[b] Replications per cell.

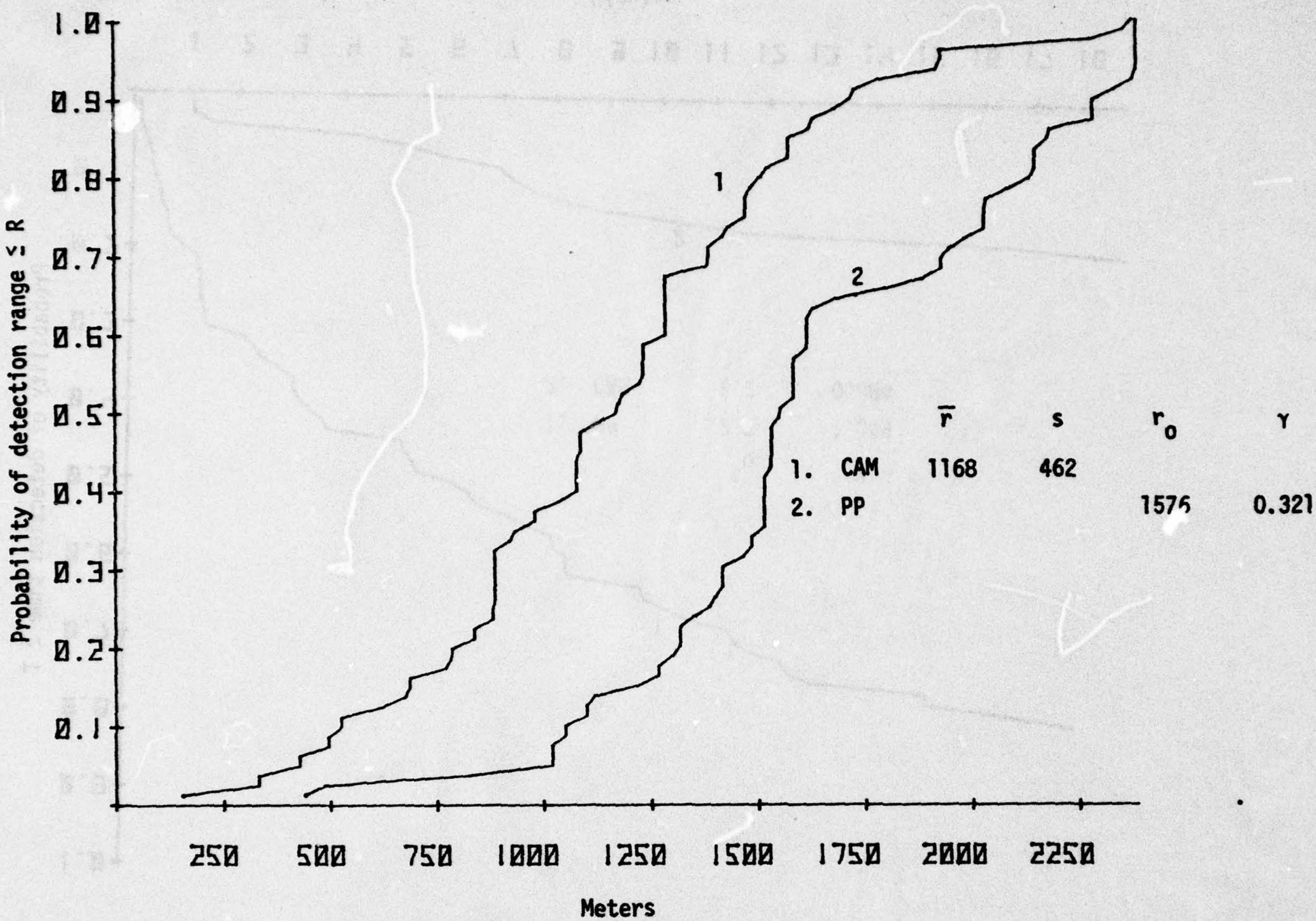

Figure 8. Cumulative distribution of detection range per tank target type, group 3 data

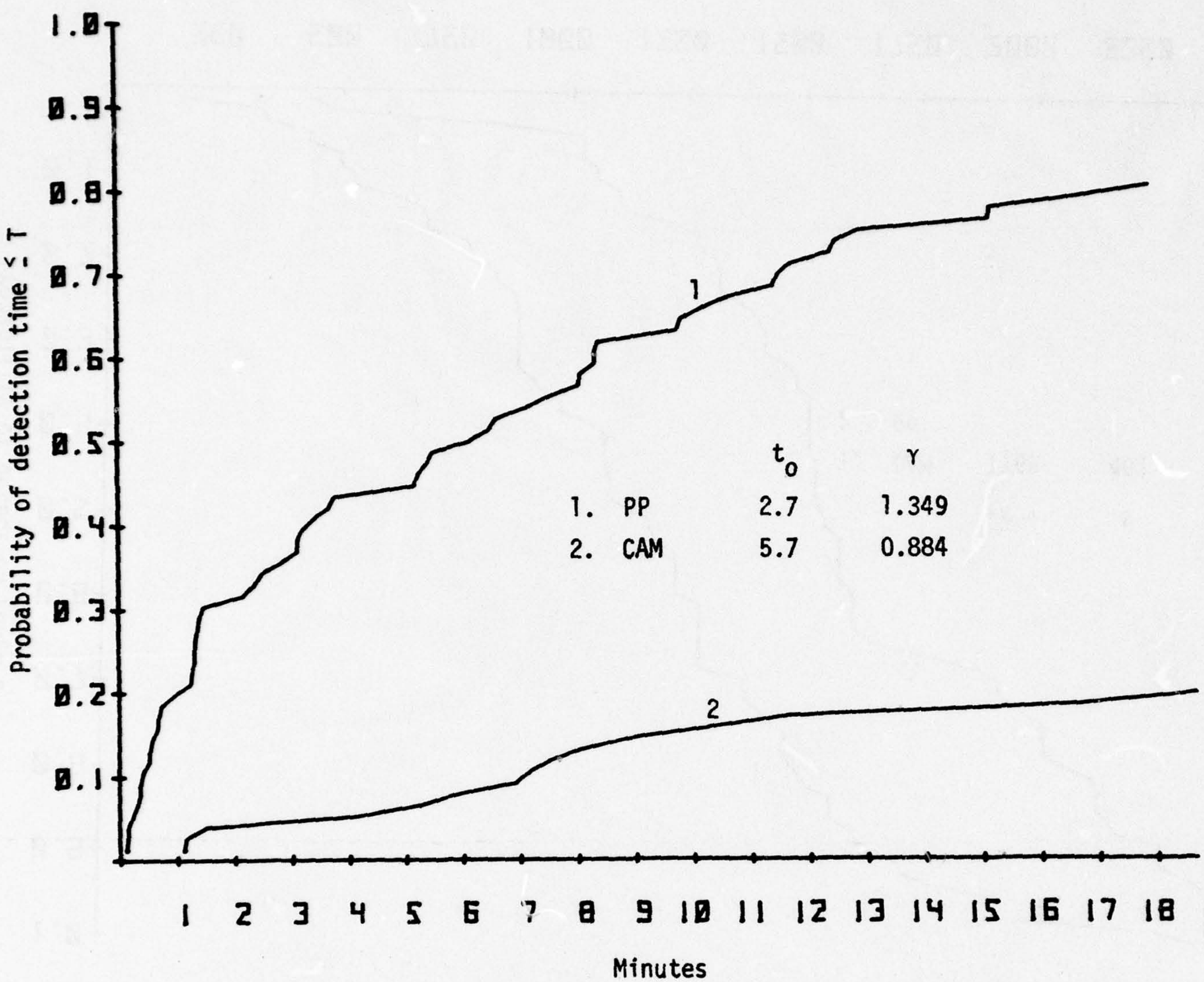

Figure 9. Cumulative distribution of time to first detection per tank target type, group 3 data

CDF of the detection times based upon the percentage of first detections.

2. An ANOVA was performed on the detection ranges; the main effects of tank type and device type were found significant. T-tests among the five levels of device type resulted in a significant difference between the following groups of devices: (1) binocular and tank periscope, (2) TOW and DRAGON devices, and (3) unaided. The binocular and periscope sighting devices afforded the observers the capability of detecting the tank targets at the longest observer-to-target ranges. These devices enabled the observers to augment their visual acuity and discrimination ability above that of the unaided eye but without sacrificing a wide field of view. The TOW and DRAGON sites were determined "next best;" even though these devices have a higher/comparable magnification capability, they are restricted to a narrow field of view. As expected the shortest observer-to-target ranges were recorded by observers using the unaided visual technique. (Figure 10 depicts the CDF of these times along with the distribution parameters.)

3. A 2x5 ANOVA (device x tank) on the times of the first target detected resulted in the significance of the main effects. Tests conducted among the five levels of device type resulted in a significant difference between the following groups of devices: (1) TOW, (2) DRAGON and periscope, and (3) unaided and binocular sighting devices. Observers using the TOW sight had the fastest detection capability, with the DRAGON and periscope sights affording the observers the second best detection capability. The unaided and binocular devices required the longest times for detection. (Figure 11 depicts the CDF and distribution parameters.) This ranking of devices is not entirely consistent with the rankings based on the range data.

4. An ANOVA on acquisition times resulted in the significance of both the main effects, tank and device type, and the interaction effect. A plot of the eight factor-level means is depicted in figure 12. The TOW sight was the sole contributor to the interaction effect as it was the only device type that had approximately the same mean acquisition time for both tank targets.

(d) Group 10 - light vegetation/rolling terrain conditions; 3 kilometers maximum range. (See table 8 for the matrix of test trials.)

1. No cumulative times were received for this group of test trials; therefore, no analysis of any kind was performed on the time data. In addition, the primary observer used binoculars for detection in all trials; therefore, an ANOVA (tank x device) could not be performed on the detection ranges.

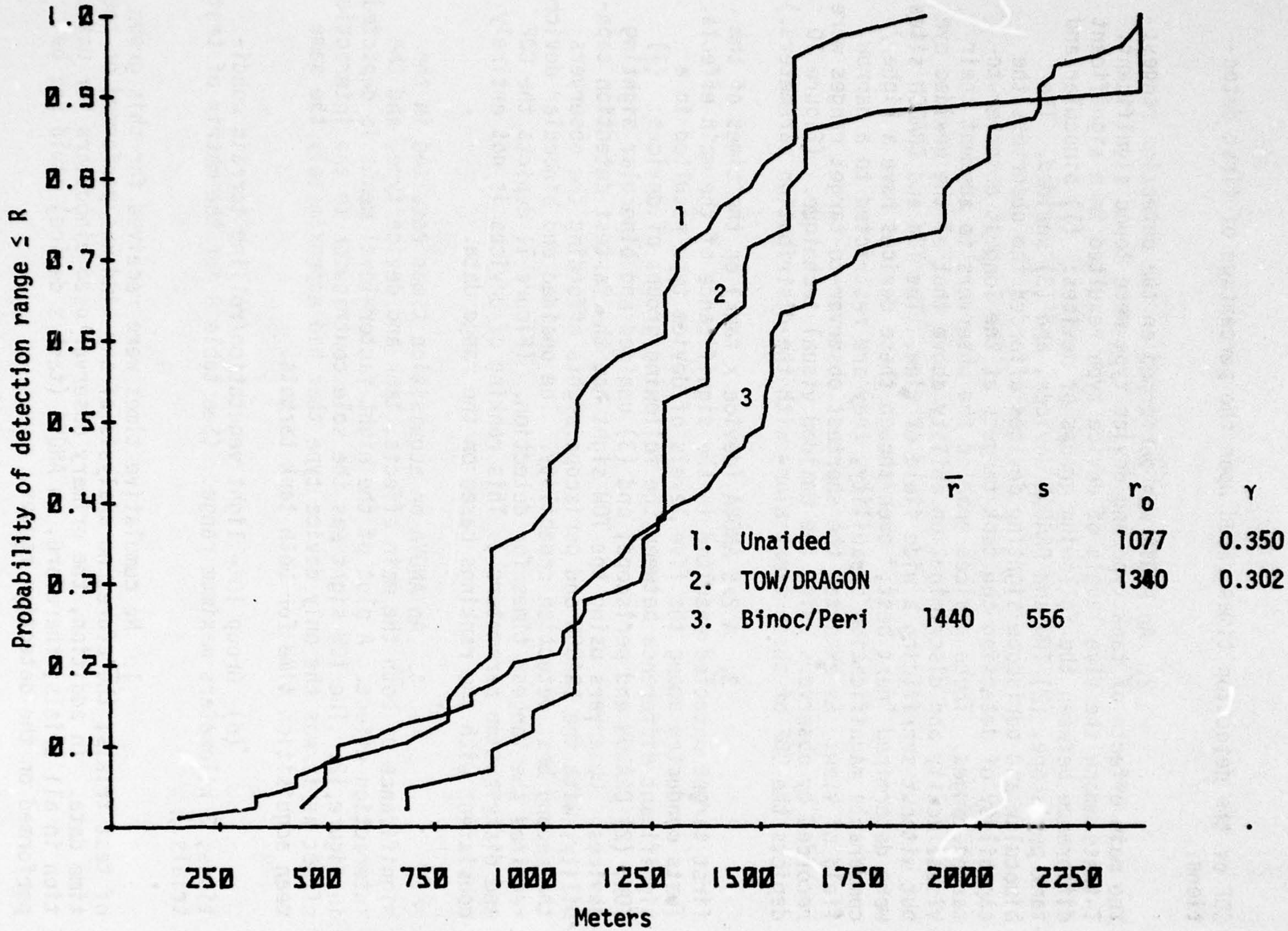

Figure 10. Cumulative distribution of detection range per device type, group 3 data

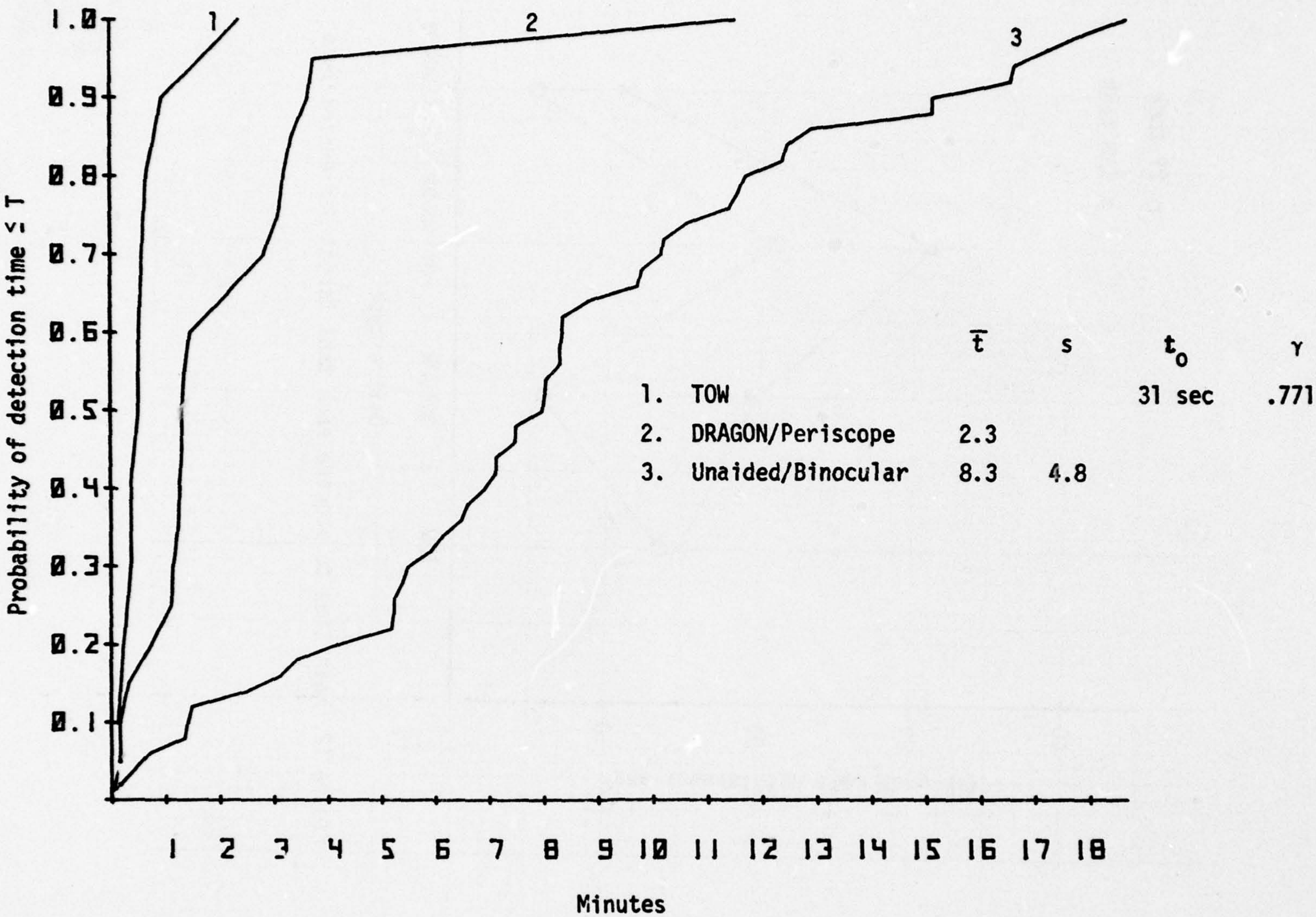

Figure 11. Cumulative distribution of time to first detection per device type, group 3 data

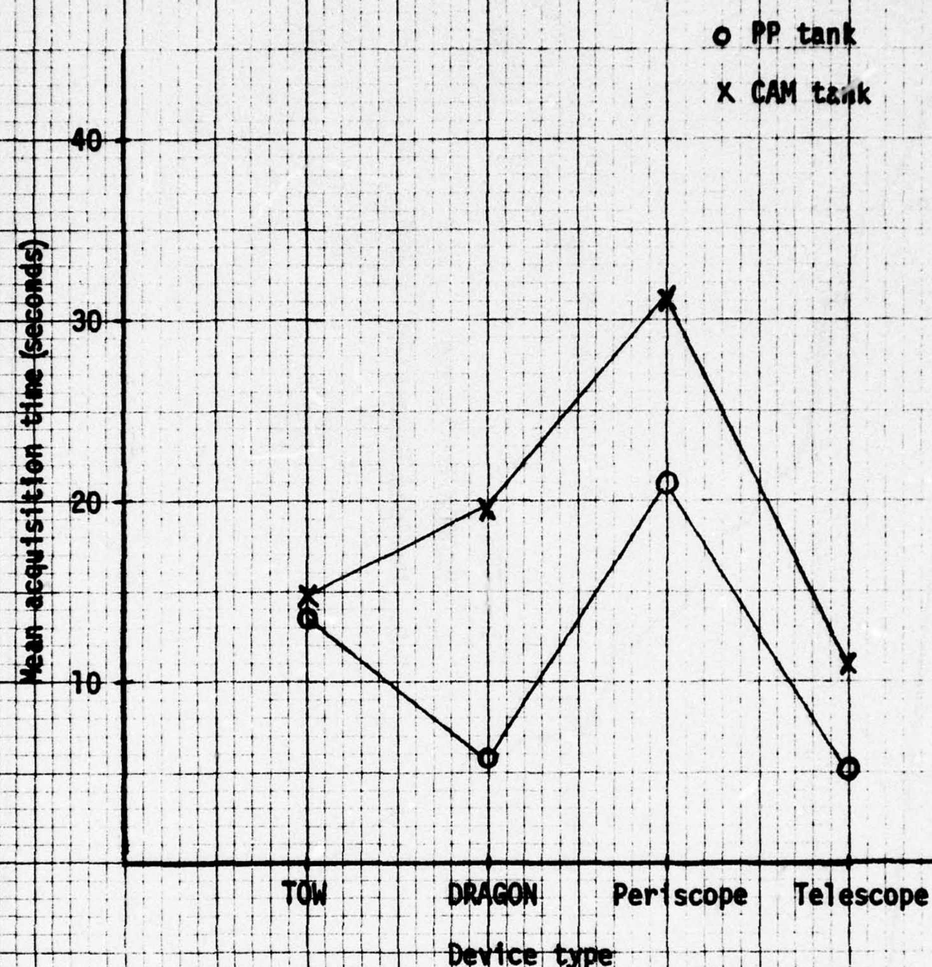

Figure 12. Mean time to acquire each tank target per device type

Table 8. Matrix of group 10 day trials - static target mode; light vegetation/rolling terrain conditions; 3 kilometers maximum range

		Test Site	
		Y	
Approach Mode	Detection, Identification/ Acquisition Device	Target Array	
		1	2
Ground	Unaided		
	Binocular/DRAGON	5[b]	5
	TOW		
	DRAGON		
	Periscope		
Wheeled Vehicle	Unaided		
	Binocular/TOW	5	5
	TOW		
	DRAGON		
	Periscope		
Tank	Unaided		
	Binoc/Peri;Tele[a]	5	5
	TOW		
	DRAGON		
	Periscopy		

[a] Acquisition was performed against target arrays 1 and 2 with the periscope and telescope, respectively.

[b] Replications per cell.

2. The detection ranges for the CAM tank were determined not to be significantly less than those of the PP tank. Figure 13 depicts the CDF and distribution parameters of the detection range data.

(2) Day/moving target mode trials.

(a) Group 2 - heavy vegetation/rolling terrain conditions; 2 kilometers maximum range. (See table 9 for the matrix of test trials.)

1. The pooled detection ranges for the CAM and PP tank targets were found to be best described as lognormal and not significantly different. This result was not unrealistic when considering the fact that the tank targets were in a dynamic mode for these test trials. The tank targets were detected at the same ranges because of the movement cue and dust signature produced by the targets. The effect of the camouflage applications was completely diminished by the dust and movement cue provided the observers. (Figure 14 depicts the CDF and distribution parameters of the range data.) This result is further supported by the probability and median time to first detection. The PP tank was detected first in 49 percent of the trials, with a median time of 10.5 seconds. The CAM tank had a median detection time of 10.9 seconds in the other 51 percent of the test trials. (The CDF of the time data based upon the percentage of first detections and the distribution parameters are depicted in figure 15.)

2. Device type was the only factor effect found significant when a 2x4 ANOVA (tank x device) was performed on the detection range data. Subsequent tests among the four levels of device type revealed that the TOW sight afforded the observers the best capability of detecting the tank targets at the longest observer-to-target ranges. The binocular and periscope devices were determined as next best. The unaided technique afforded the observers the poorest detection capability. The fact that the targets were moving allowed the observers using the TOW sight to "zero in" on the tank targets. It is not known why the binocular and periscope devices did not exhibit this "zeroing in" effect. (Possibly the superior power of the TOW made the difference at this test site.) The "zeroing in" effect is seen in figure 16 by the steep descent in the plot of TOW detection ranges at the maximum range.

3. An ANOVA (tank x device) performed on the first detect times resulted in the nonsignificance of all effects. Pooling the data across tank and device type resulted in a mean detection time of 15.8 seconds with a standard deviation of 12.9 seconds.

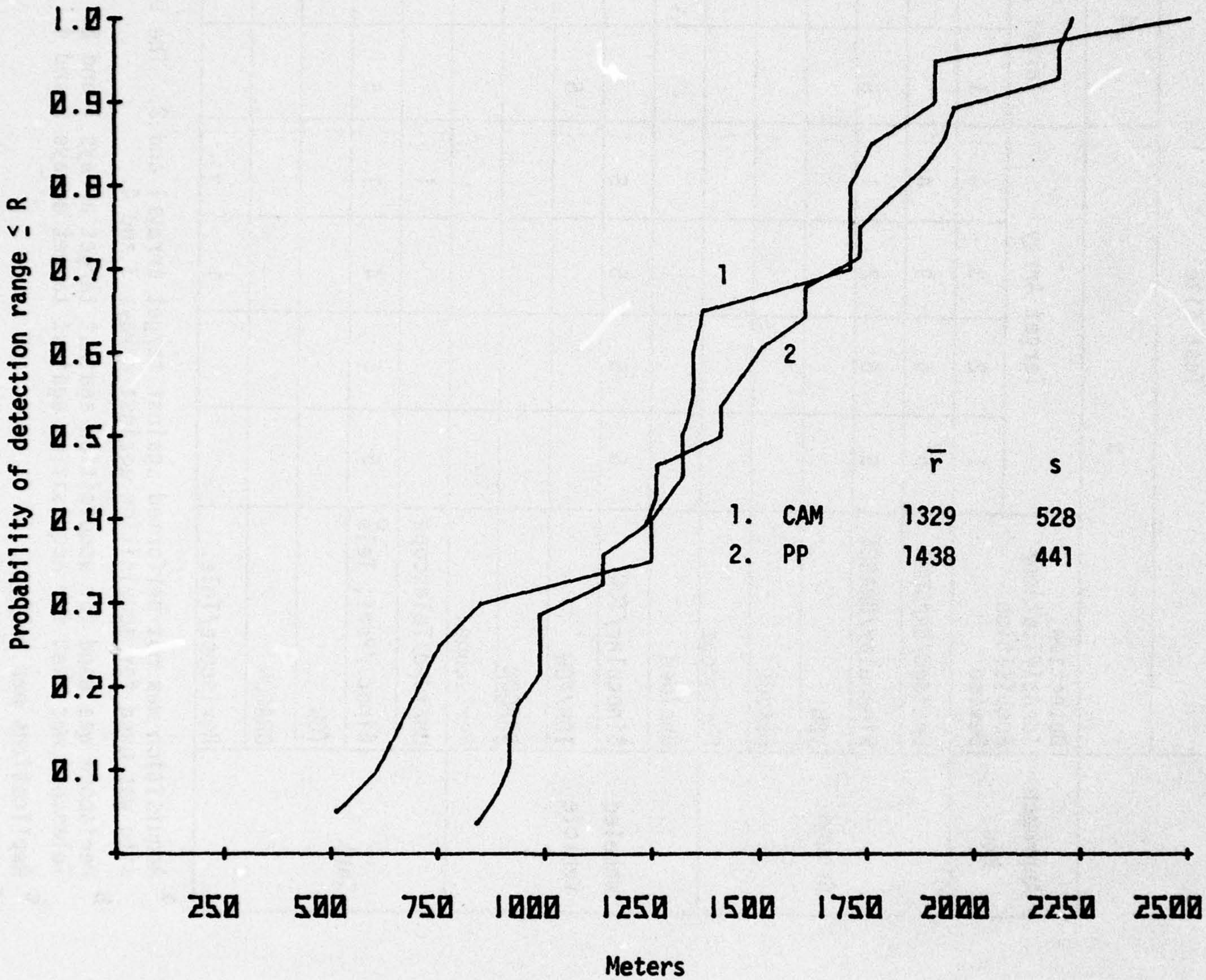

Figure 13. Cumulative distribution of detection range per tank type, group 10 data

Table 9. Matrix of group 2 day trials - dynamic target mode; heavy vegetation/rolling terrain conditions; 2 kilometers maximum range

		Test Site					
		X				Y[d]	
Approach Mode	Detection, Identification/ Acquisition Device	Target Array				Target Array	
		1	2	3	4	1	2
Ground	Unaided/DRAGON[a]	5[c]	5	3	4		
	Binocular/DRAGON	5	5	2	1	5	4
	TOW						
	DRAGON						
	Periscope						
Wheeled Vehicle	Unaided						
	Binocular/TOW	5	5	5	5		
	TOW/TOW					5	5
	DRAGON						
	Periscope						
Tank	Unaided/Telescope				1		
	Binoc./Peri, Tele[b]	5	5	4	1	5	4
	TOW						
	DRAGON						
	Periscope/Tele.			1	3		

[a] Acquisition was not performed against target arrays 1 and 2. The DRAGON site was used for acquisition against arrays 3 and 4.

[b] Periscope was used for acquisition against target arrays 1 and 2. Telescope was used for acquisition against target arrays 3 and 4.

[c] Replications per cell.

[d] These data represent group 11 test trials conducted under the same experimental conditions as group 2.

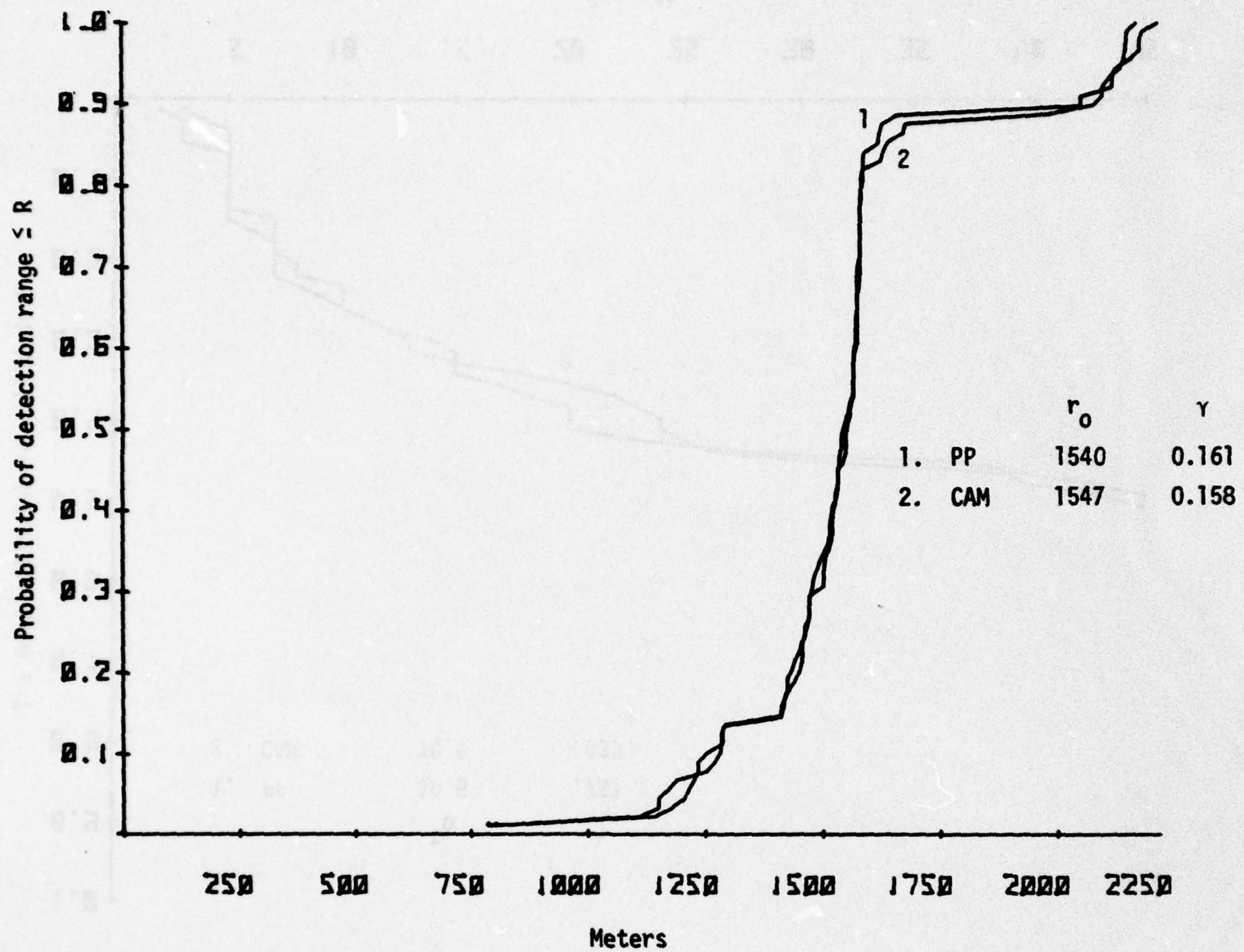

Figure 14. Cumulative distribution of detection range per tank target type, group 2 data

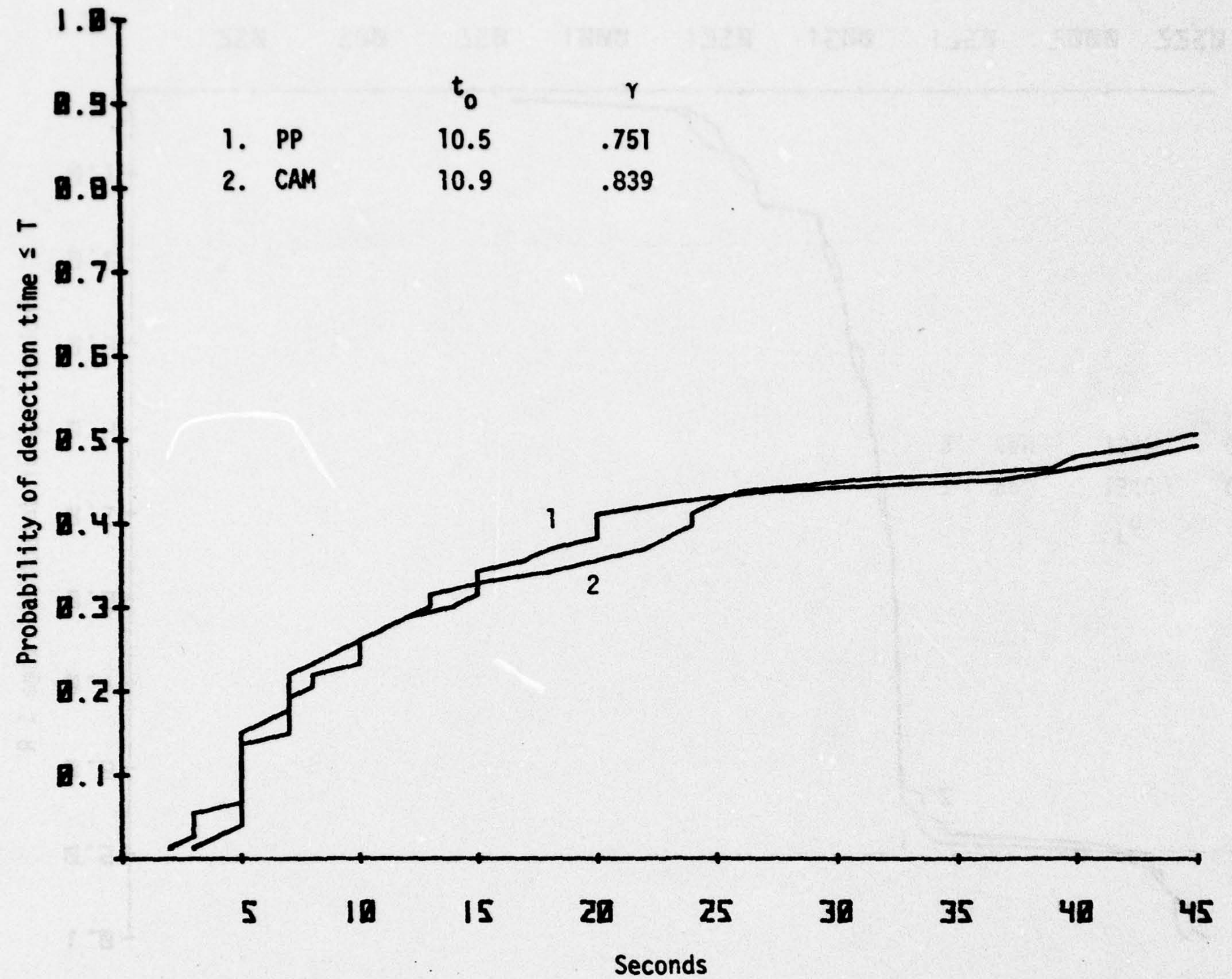

Figure 15. Cumulative distribution of time to first detection per tank target type, group 2 data

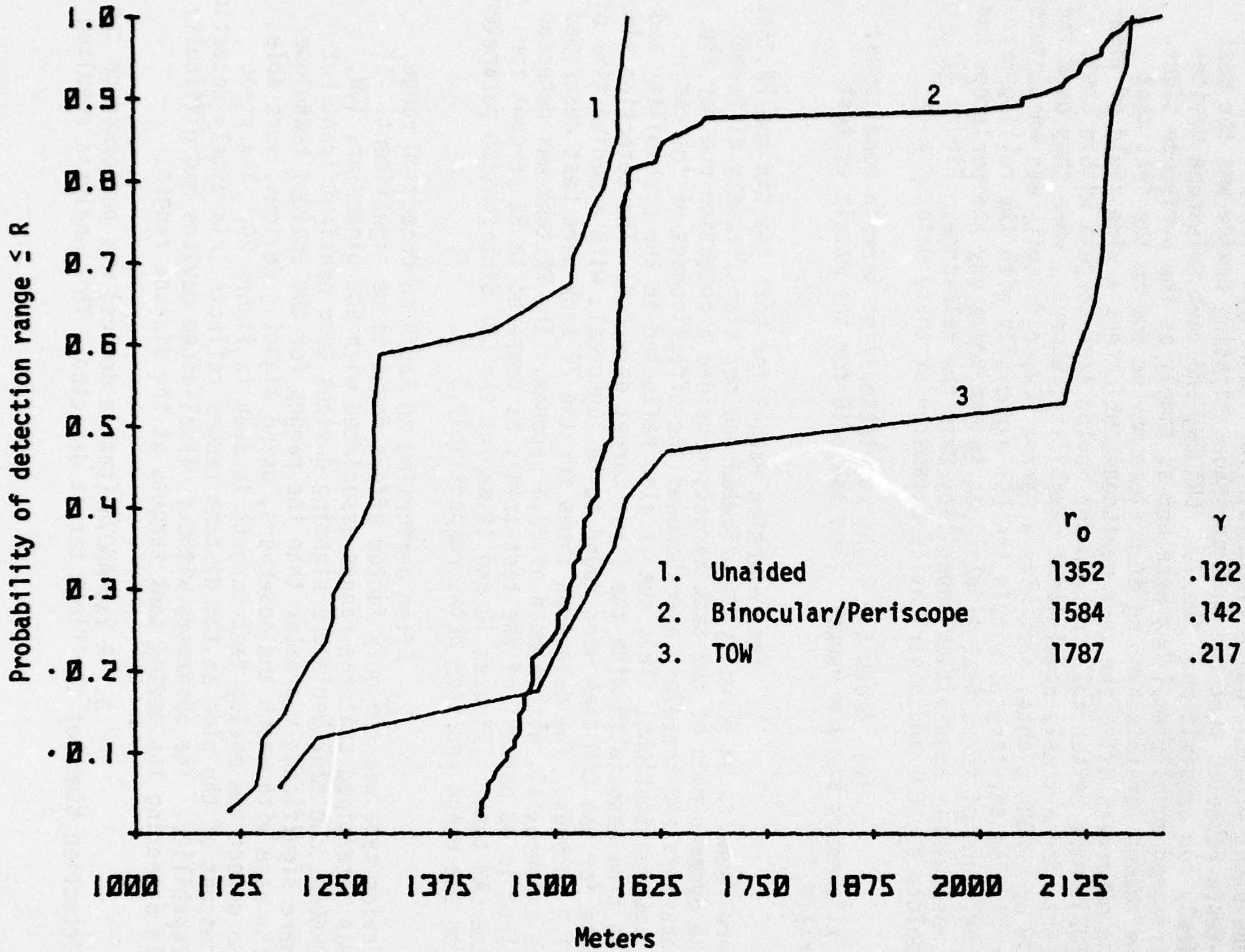

Figure 16. Cumulative distribution of detection range per device type, group 2 data

4. A 2x4 ANOVA (tank x device) on acquisition times resulted in the significance of the factor device type only. (This is consistent with the other findings; i.e., tank type nonsignificant.) T-tests revealed that the tank periscope sighting device was the most timely for acquisition. The TOW, DRAGON, and tank telescope devices performed equally well but were not as timely as the periscope sight. The reason for this ranking of devices may be due to the fact that the observers using the tank periscope, which has a wide field of view (FOV), were better able to keep the moving tank targets within their sights for a timely acquisition capability; whereas, when they used the TOW or DRAGON sights, each with a narrow FOV, difficulty was encountered in keeping the targets within the FOV especially with the rolling terrain conditions of these test trials. It is not known why the periscope had a more timely acquisition capability than the telescope. Figure 17 depicts the CDF and distribution parameter of these data.

(b) Group 5 - light vegetation/flat terrain conditions; 2 kilometers maximum range. (See table 10 for the matrix of test trials.)

1. The detection ranges for both the CAM and PP tank were found to be normally distributed and not significantly different. The dynamic mode of the tank targets provided a detection cue for the observers and therefore overshadowed the effectiveness of the camouflage applications. This cue is also reflected in the probability and the time associated with the first target detected. The detection time data for the CAM tank were found to be lognormal, with a median time of 11.0 seconds. The detection times for the PP tank were best described as exponential, with a mean of 12.4 seconds. The PP tank was detected first in 48 percent of the test trials as compared to 52 percent for the CAM tank. (Figures 18 and 19 depict the CDF distribution parameters for the range and time data, respectively.)

2. After performing an ANOVA on detection range, device type was the only factor effect found to be significant. It was determined that the ranges associated with the binocular, TOW, DRAGON, and tank periscope sighting devices were nonsignificant but were significantly greater than the ranges for the unaided technique. The ease with which the observers, using sighting devices, were able to detect the moving tank targets is seen in figure 20. The steep descent of the plot at the distant ranges reflects this timely detection capability. The observers without visual-aided devices had difficulty in detecting the moving tank targets at the distant ranges.

3. A 2x5 ANOVA (tank x device) was performed on the detection times of the first target detected. This analysis resulted in

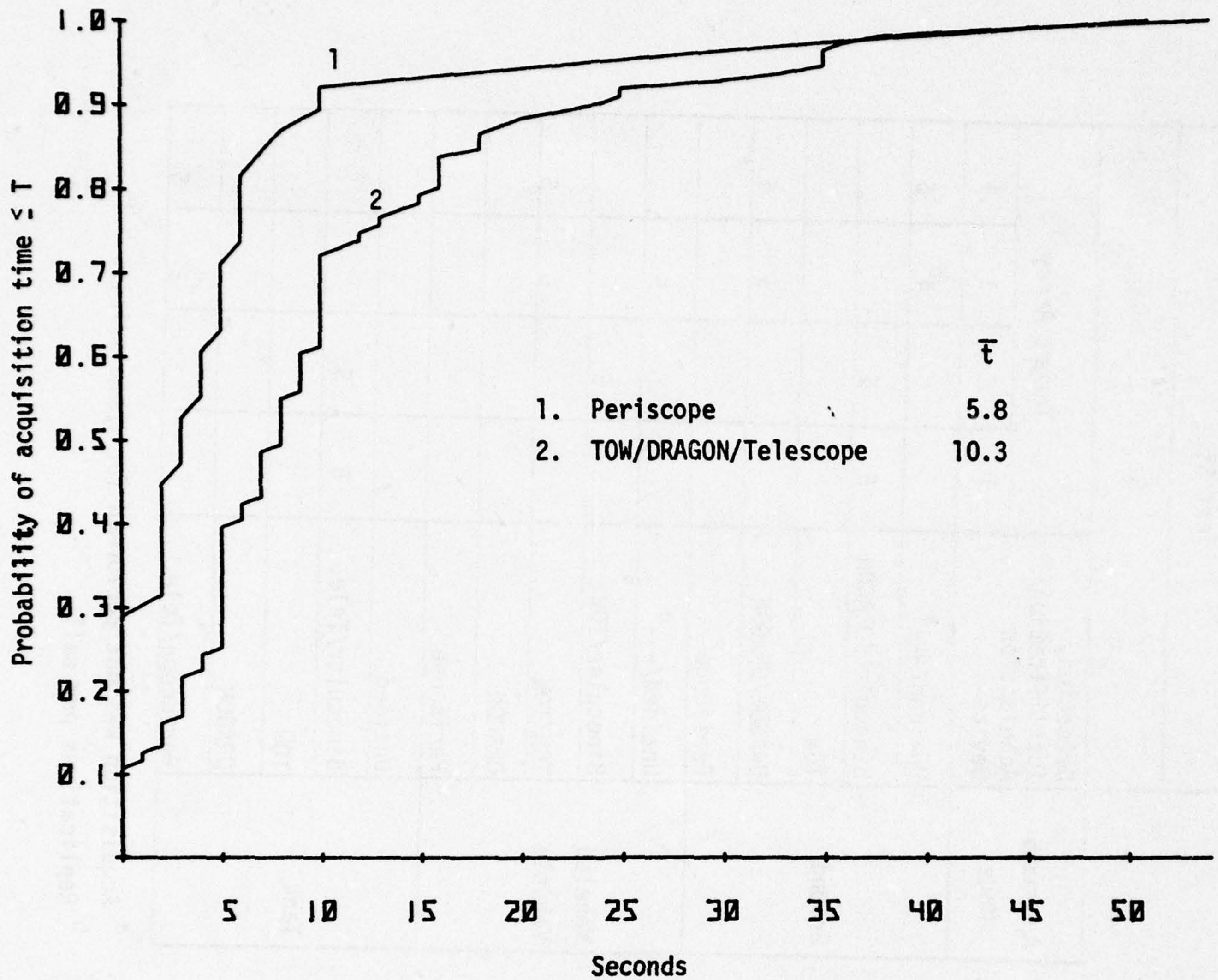

Figure 17. Cumulative distribution of acquisition time per device type, group 2 data

Table 10. Matrix of group 5 day trials - dynamic target mode; light vegetation/flat terrain conditions; 2 kilometers maximum range

		Test Site			
		S			
Approach Mode	Detection, Identification/ Acquisition Device	Target Array			
		1	2	3	4
Ground	Unaided/---[a]			4[b]	6
	Binocular/DRAGON	5	5		
	TOW				
	DRAGON/DRAGON			5	5
	Periscope				
Wheeled Vehicle	Unaided/---[a]			5	
	Binocular/TOW	5	5		
	TOW/TOW			5	5
	DRAGON				
	Periscope				
Tank	Unaided				
	Binocular/Tele.	5	5		
	TOW				
	DRAGON				
	Periscope/Tele.			5	5

[a] Acquisition was not performed for these trials.

[b] Replications per cell.

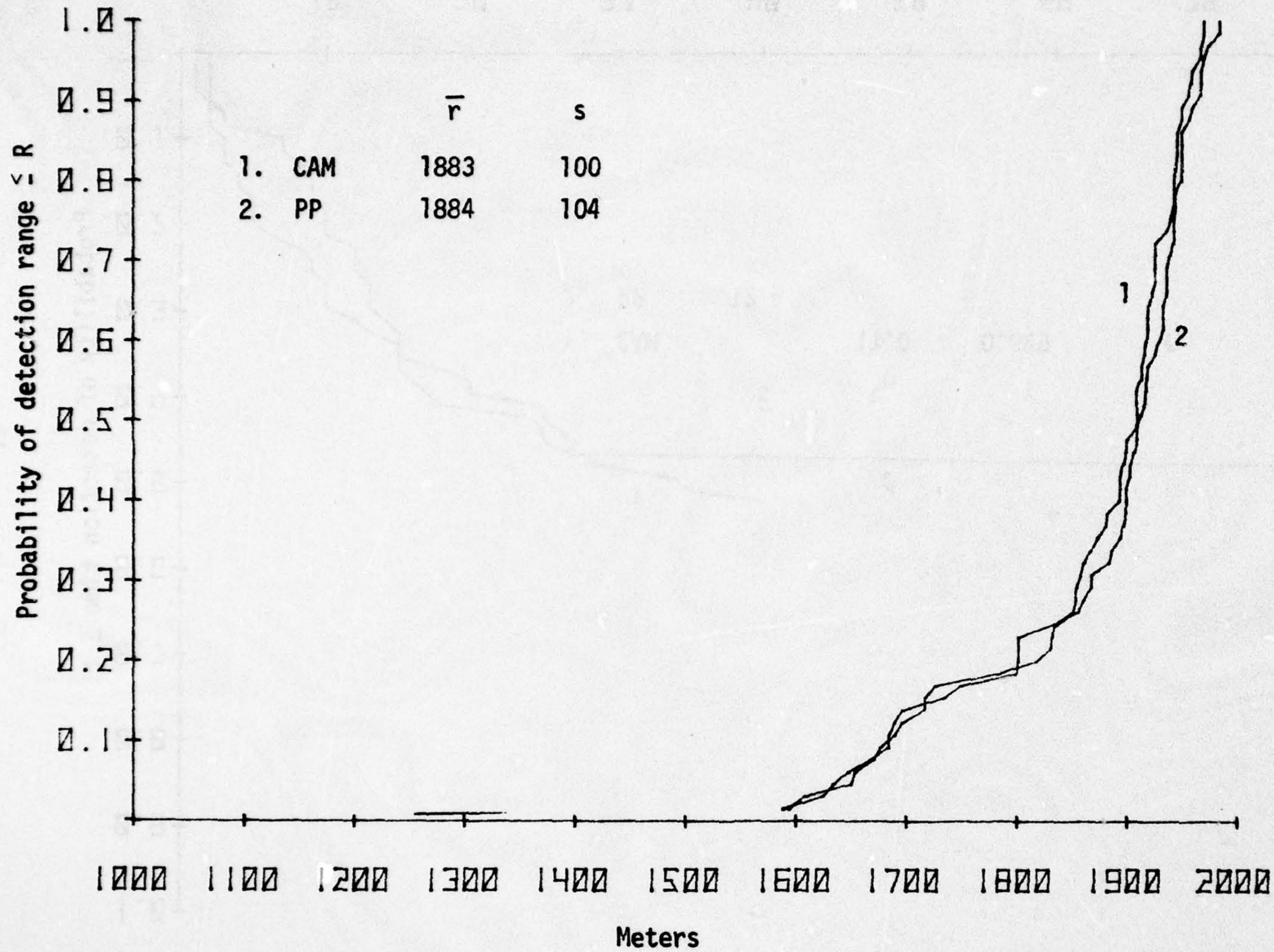

Figure 18. Cumulative distribution of detection range per tank target type, group 5 data

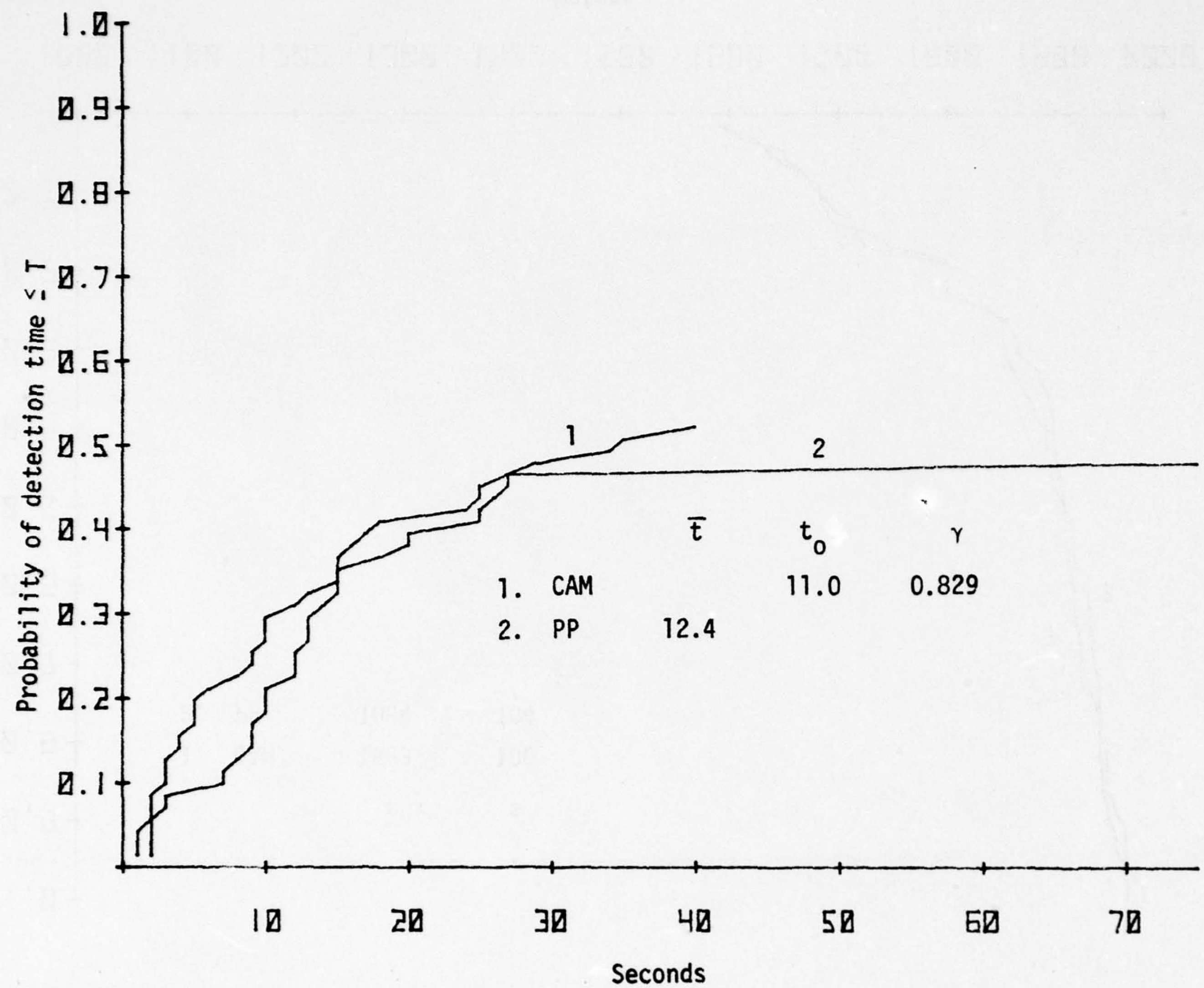

Figure 19. Cumulative distribution of time to first detection per tank target type, group 5 data

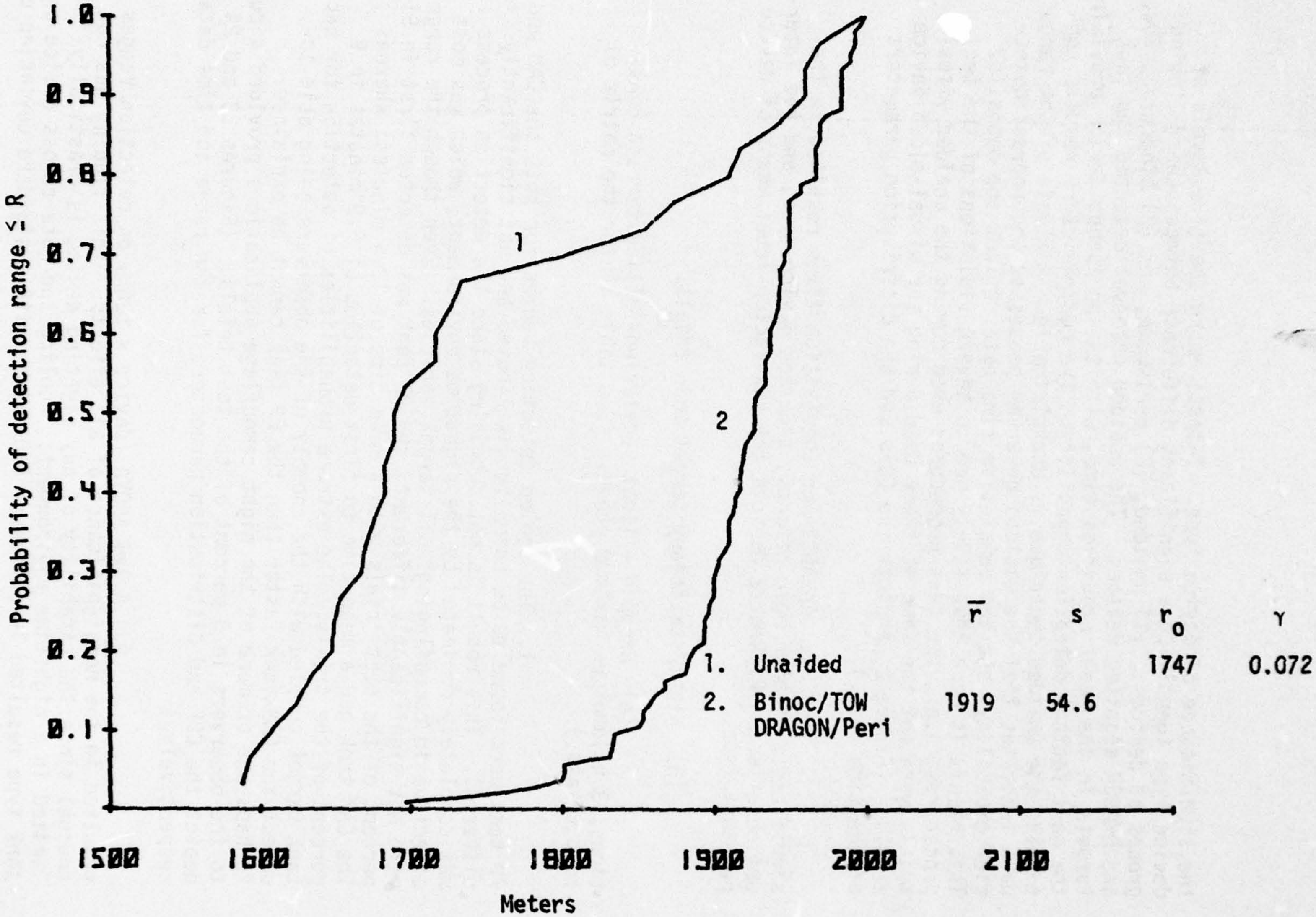

Figure 20. Cumulative distribution of detection range per device type, group 5 data

the significance of device type. T-tests among the five levels of device type identified a significant difference between the following groups of devices: (1) unaided, (2) periscope, and (3) binocular, TOW, and DRAGON sighting devices. The unaided observer detected the tank targets in the least amount of time, with the periscope device providing the next fastest detection capability. The contradictory results concerning the unaided technique is unexplainable. Analysis of the range data indicates that the unaided observer possessed the poorest detection capability, but the cumulative time data reflect the opposite. This result is more than likely due to severe violations of the test procedures; i.e., the test procedures used during the unaided visual trials were not the same as those used during the visual-aided device trials. (Figure 21 depicts the CDFs and the distribution parameters of the time data.)

4. An ANOVA on acquisition times resulted in the significance of both main effects, tank and device type, and the interaction effect. Figure 22 depicts the six factor-level means of device per tank type.

(3) Night/stationary target mode trials.

(a) Group 4 - light vegetation/rolling terrain conditions; 3 kilometers maximum range. (See table 11 for the matrix of test trials.)

1. The pooled detection ranges for both the CAM and PP tank were found to be normally distributed and not significantly different. This result is not suprising since the detection process was completely dominated by the nighttime environment, which was most effective in "camouflaging" all target vehicles. Even though the ranges were not significantly different, the PP tank was detected first in 91 percent of the test trials with a mean time of 13.4 minutes; whereas the CAM tank had a mean time to first detection of 9.9 minutes in 9 percent of the trials. The extreme probabilities of detection for each tank target coupled with the anomaly of the observers being able to detect the CAM tank faster than the PP tank cannot be explained. Perhaps one or more of the night camouflage applications provided a cue to the observers in 9 percent of the test trials. (Figures 23 and 24 depict the CDF and distribution parameters for the range and time data, respectively.)

2. A 2x5 ANOVA (device x tank) on detection ranges resulted in the nonsignificance of all effects. This finding was not unusual since the capability of any sighting device is drastically limited in a nighttime environment. Pooling the data across device and tank type resulted in a mean of 630 meters with a standard deviation of 484 meters.

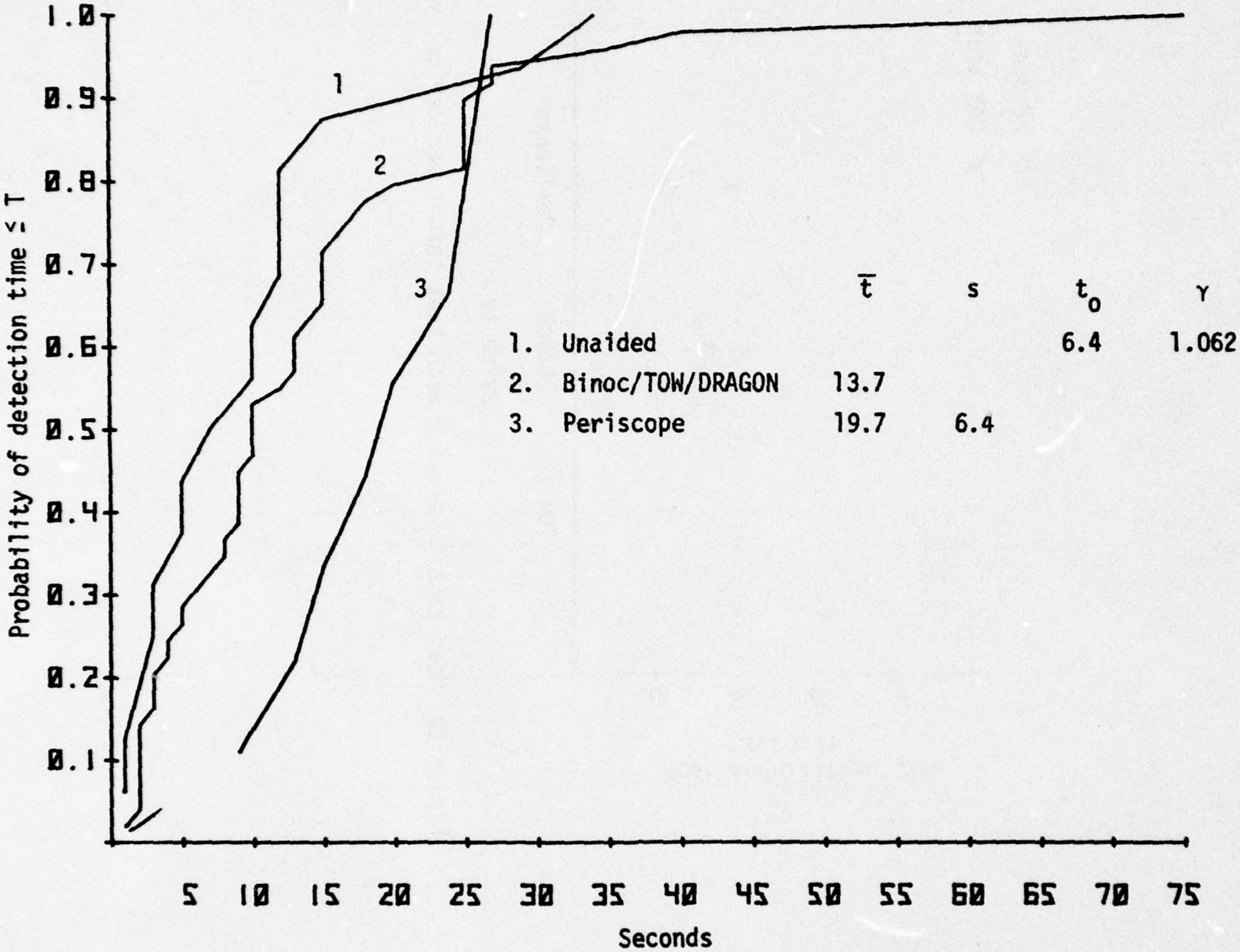

Figure 21. Cumulative distribution of time to first detection per device type, group 5 data

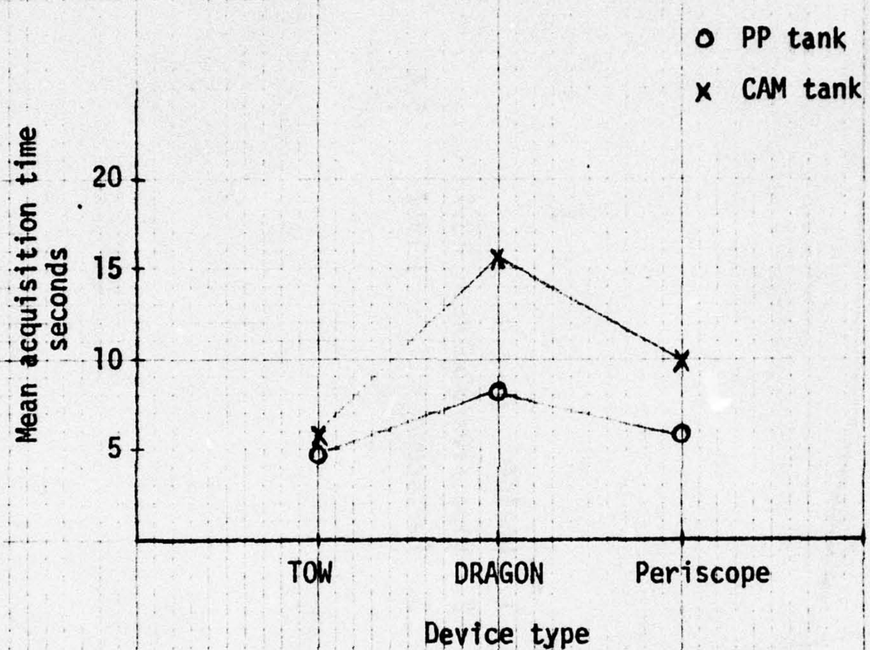

Figure 22. Mean time to acquire each tank target per device type

Table 11. Matrix of group 4 night trials - static target mode; light vegetation/rolling terrain conditions; 3 kilometers maximum range

		Test Site			
		U			
Approach Mode	Detection, Identification/ Acquisition Device	Target Array			
		1	2	3	4
Ground	Unaided/---[a]	5[c]		4	8
	Binocular				
	TOW				
	Periscope				
	NVD(GL)/NVD(GL)	5			
Wheeled Vehicle	Unaided				
	Binocular/---[a]	6		4	8
	TOW/TOW[b]	6			
	Periscope				
	NVD(GL)				
Tank	Unaided				
	Binocular				
	TOW				
	Periscope/NVD(GL)	6		2	6
	NVD(GL)				

[a] Acquisition was not performed for these trials.

[b] Equipped with AN/TVS-5 sight.

[c] Replications per cell.

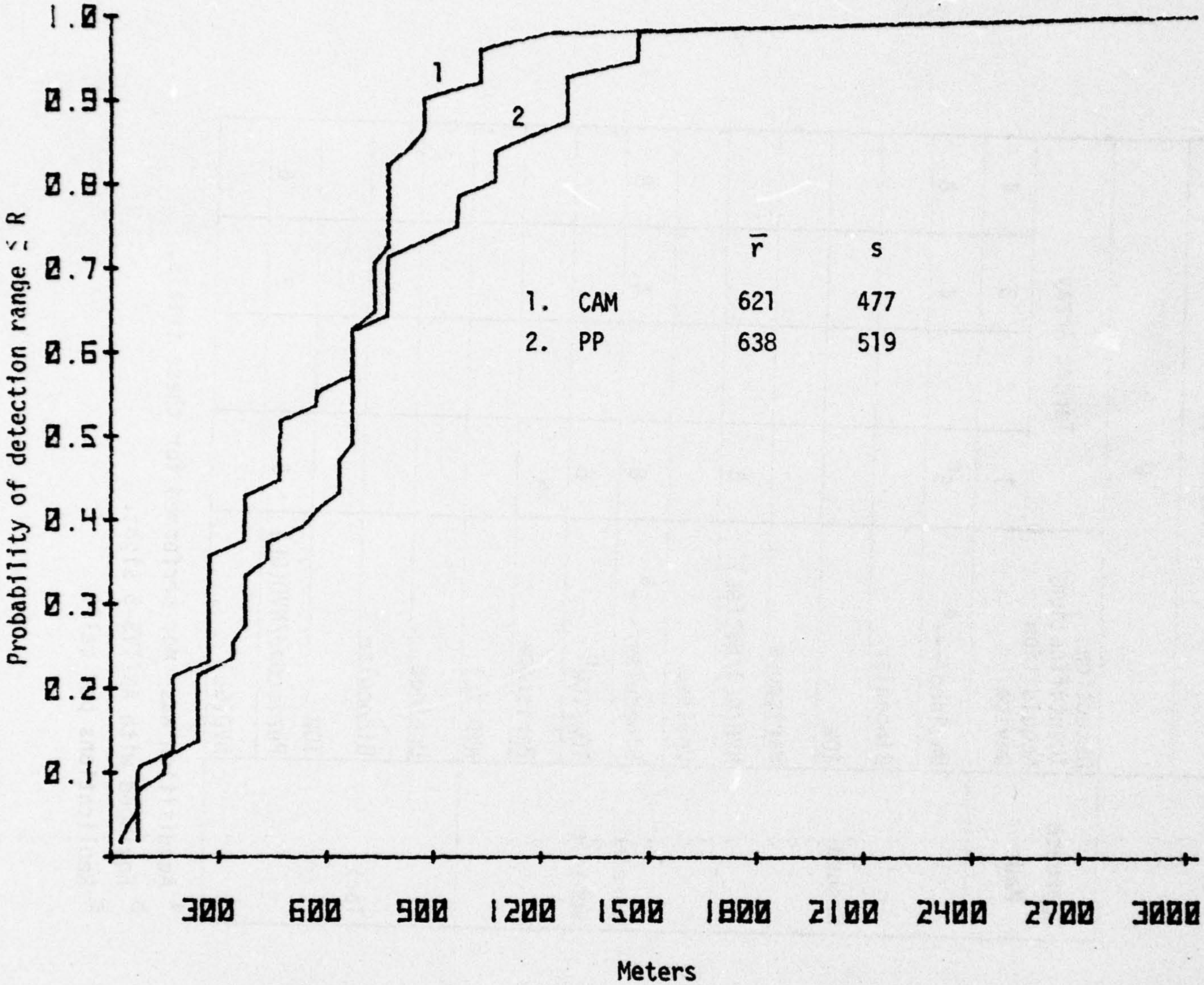

Figure 23. Cumulative distribution of detection range per tank target type, group 4 data

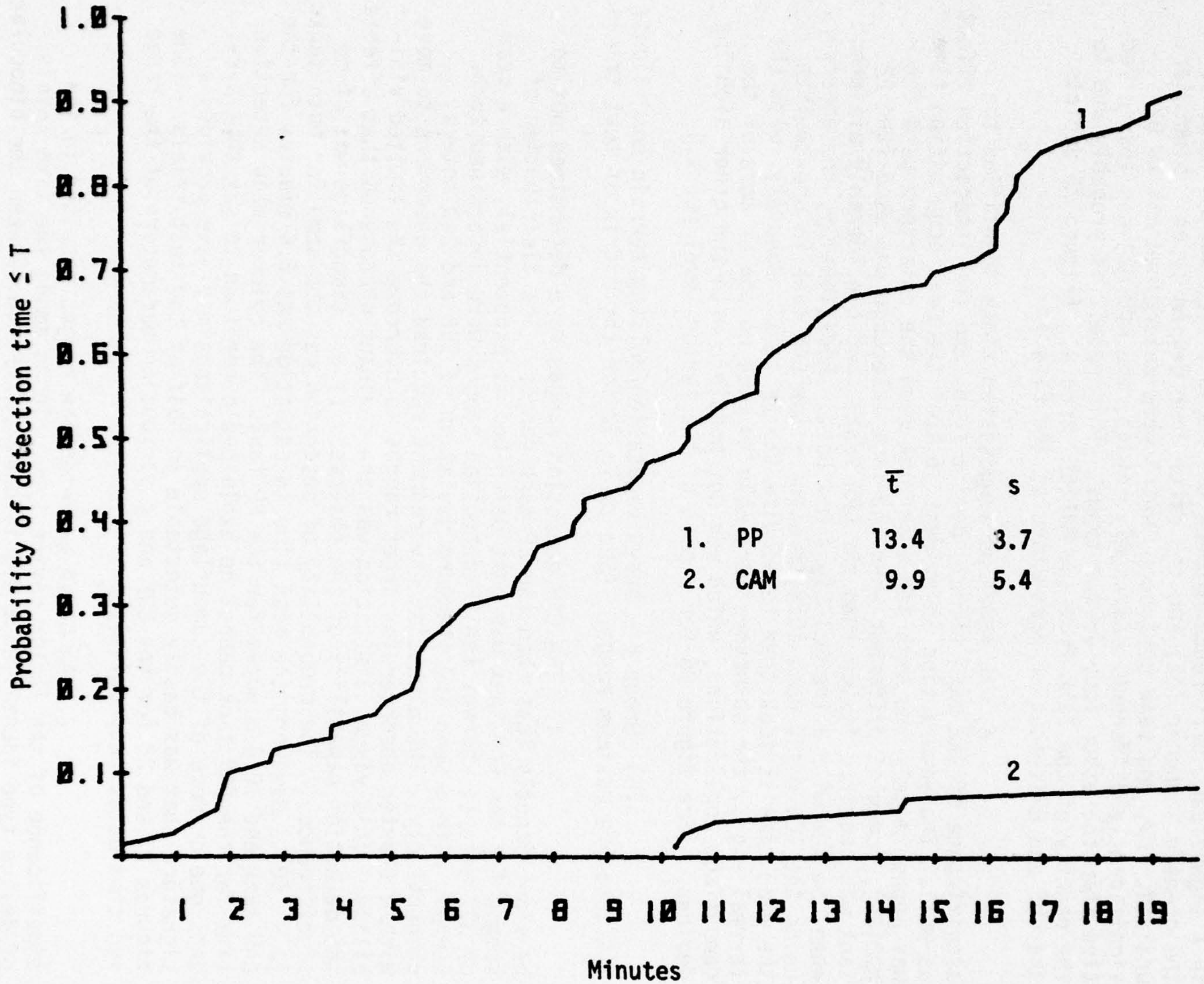

Figure 24. Cumulative distribution of time to first detection per tank target type, group 4 data

3. After performing an ANOVA on the times of the first target detected, the main effects of device and tank type were found significant. Tests among the five levels of device type resulted in a significant difference between the night vision device (NVD) of the grenade launcher (GL) and the other four device types: binocular, unaided, TOW, and tank periscope, which were determined not to be significantly different. Strangely enough, the NVD(GL) was less effective than the other four device types. This result is probably due to the paucity of the data from the NVD(GL) trials. (Figure 25 depicts the CDF and distribution parameters of the data.)

4. An ANOVA on acquisition times identified the significance of the main effect, device type, and the interaction effect as well. The interaction is evident in that the mean acquisition time was approximately the same for each tank when the observers used the NVD(GL), somewhat different when the tank telescope was used (the PP tank was acquired faster than the CAM tank), and considerably different when the TOW with a thermal sight was used. Additionally, the observers using the TOW sight were able to acquire the CAM tank in one-twelfth the mean time it took them to acquire the PP tank. Possibly, with the thermal sight, the observers were able to pick up one or more of the camouflage applications, which was not possible with the other sighting devices. (See figure 26 for a plot of the factor level means.)

(b) Group 6 - heavy vegetation/rolling terrain conditions; 2 kilometers maximum range. (See table 12 for the matrix of test trials.)

1. The CAM detection ranges were determined not to be significantly less than the PP tank ranges. The distribution of ranges for the CAM tank was best described as exponential, with a mean of 377 meters; whereas the PP detection ranges were determined to be normal, with a mean and standard deviation of 356 and 240 meters, respectively. The nighttime environment required the observers to move within shorter observer-to-target ranges to overcome the limited visibility. This visual limitation was the dominant phenomenon that affected the detection capability of the observers (i.e., camouflage was of no significance). The probability of detection was the same for both tanks ($p < .50$). However, the mean time to detection was 6.4 minutes for the CAM tank and 10.4 minutes for the PP tank. The quicker mean detection time for the CAM tank cannot be explained other than to say that perhaps one or more of the camouflage applications may have provided a signature that was easily detectable in half of the test trials. (See figures 27 and 28 for the CDF and distribution parameters of the range and time data, respectively.)

2. An ANOVA on detection ranges resulted in the significance of the factor device type. Tests among the five levels of device type identified a significant difference between the binocular,

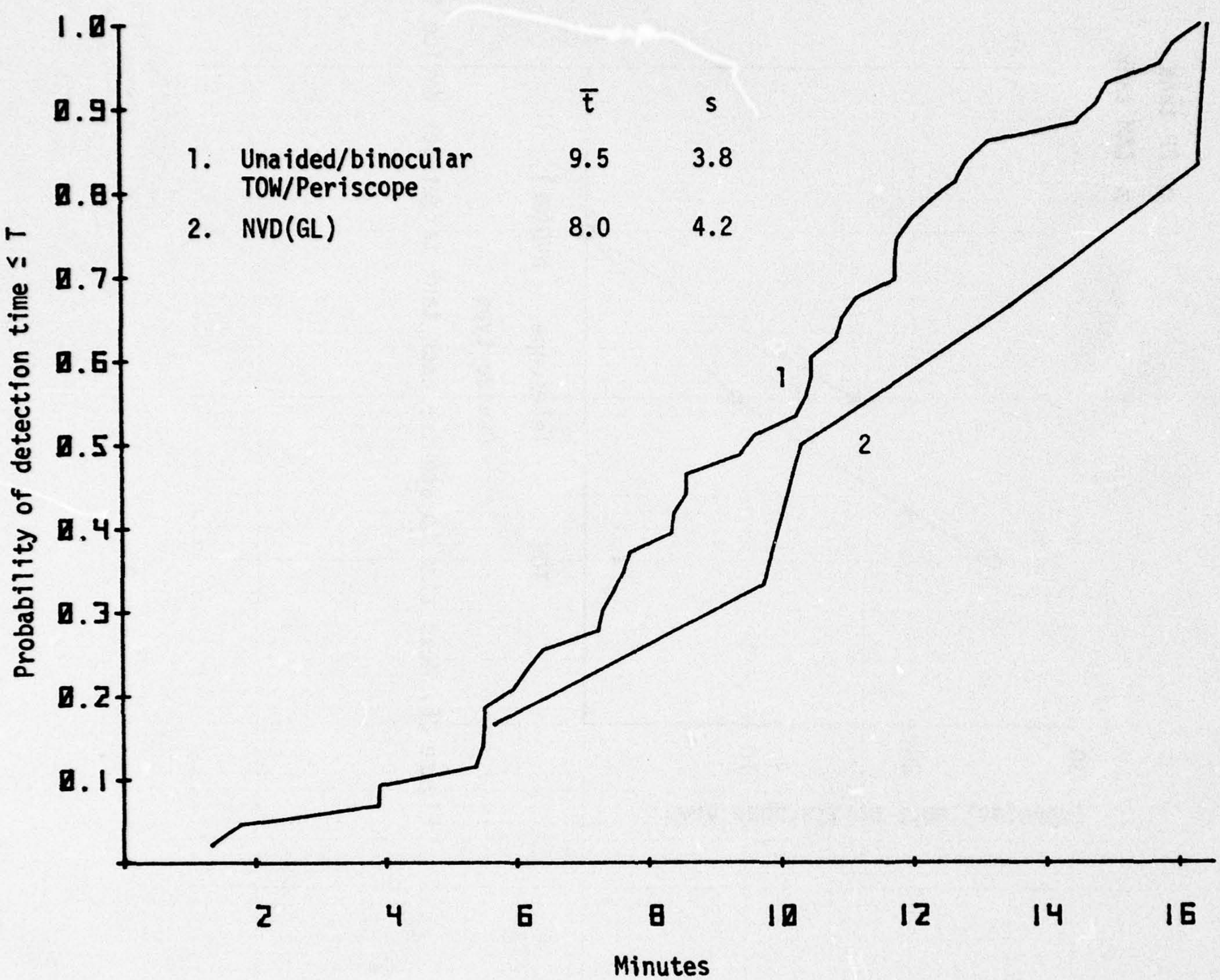

Figure 25. Cumulative distribution of time to first detection per device type, group 4 data

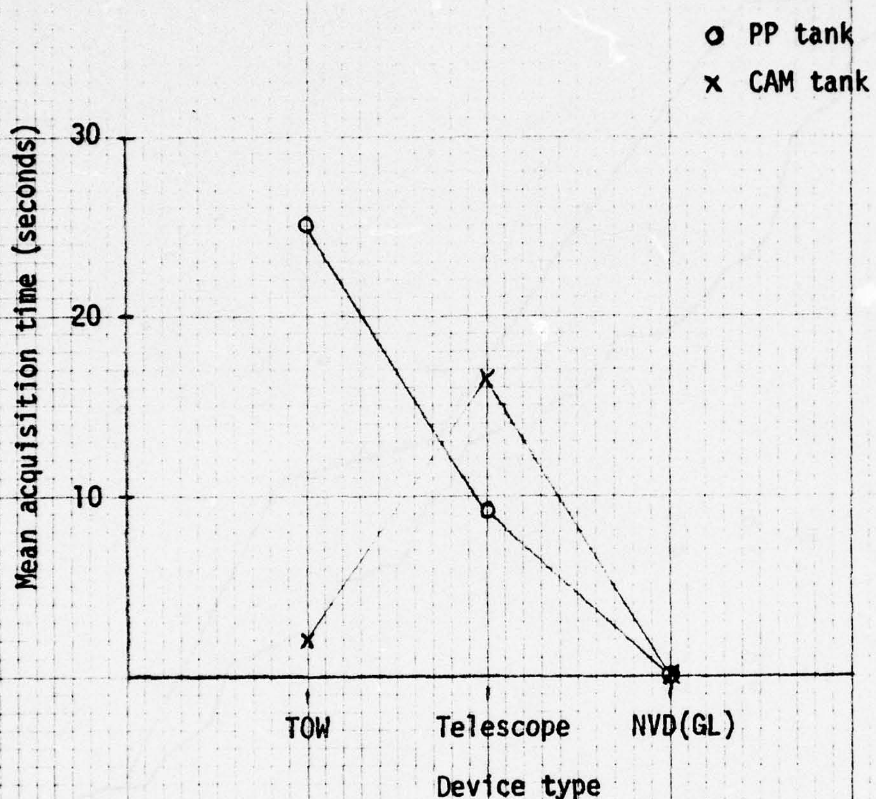

Figure 26. Mean time to acquire each tank target per device type

Table 12. Matrix of group 6 night trials - static target mode; heavy vegetation/rolling terrain conditions; 2 kilometers maximum range

		Test Site	
		V	
Approach Mode	Detection, Identification/ Acquisition Device	Target Array	
		1	2
Ground	Unaided		
	Binocular/---[a]	5[b]	5
	TOW		
	NVD(RR)		
	NVD(GL)/NVD(GL)	5	5
Wheeled Vehicle	Unaided		
	Binoculars		
	TOW/TOW	5	5
	NVD(RR)/NVD(RR)	5	5
	NVD(GL)		
Tank	Unaided		
	Binoculars		
	Periscope/Peri.	5	5
	NVD(RR)		
	NVD(GL)		

[a] Acquisition was not performed for these trials.

[b] Replications per cell.

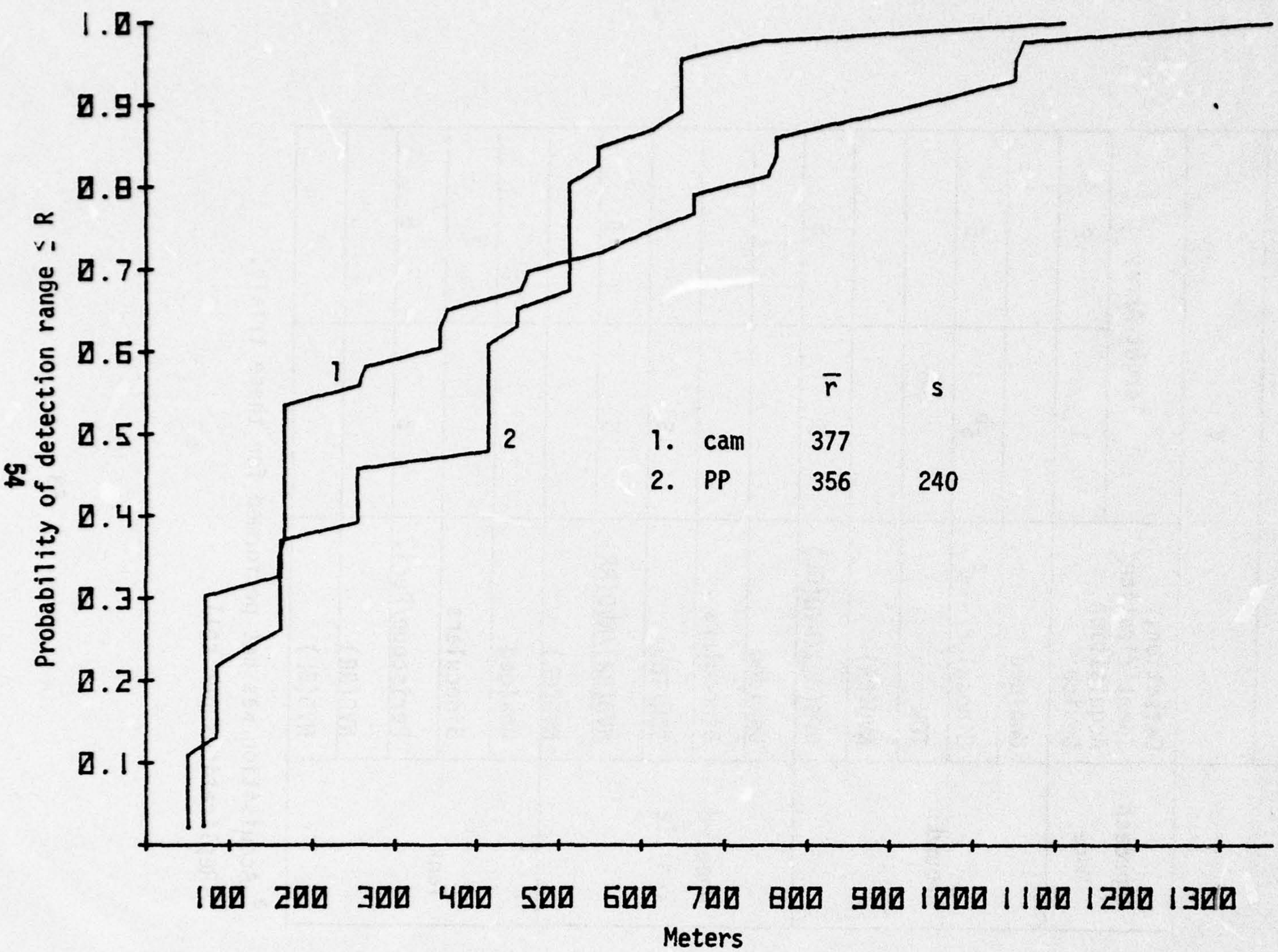

Figure 27. Cumulative distribution of detection range per tank target type, group 6 data

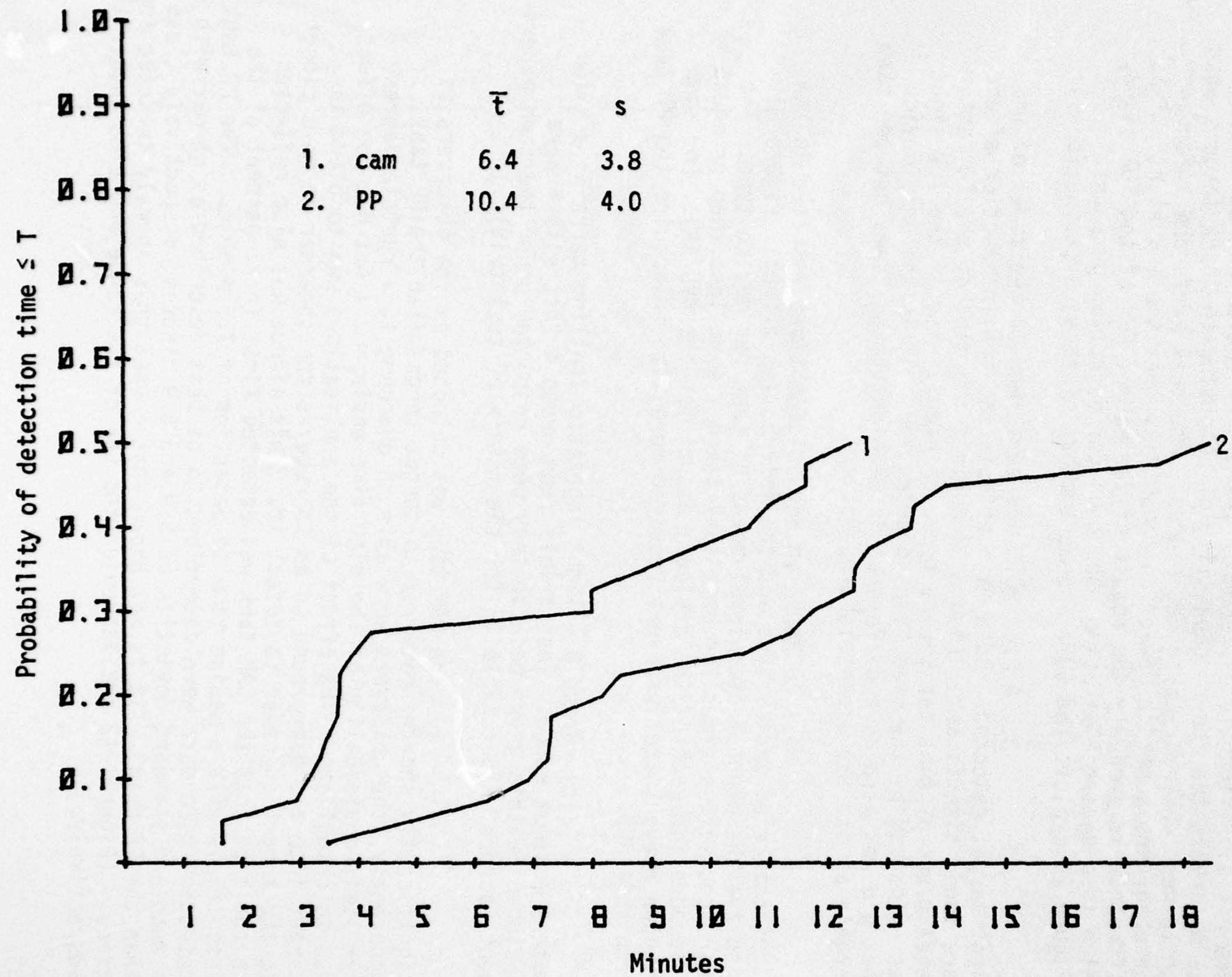

Figure 28. Cumulative distribution of time to first detection per tank target type, group 6 data

TOW (with a thermal sight), tank periscope, and the night vision devices (NVD). The NVD of the grenade launcher (GL) and recoilless rifle (RR) were not significantly different. The NVD of the GL and RR afforded the observers the "best" capability of detecting the tank targets at the longest observer-to-target ranges. The tank periscope afforded the observers a better detection capability than the TOW sight. This difference is probably the result of the narrow FOV of the TOW sight, which is a severe limitation when used for detection purposes. (Figure 29 depicts the CDFs and parameters of these distributions.)

3. A 2x5 ANOVA was performed on the times of the first target detected. Both main effects and the interaction effect were found significant. Figure 30 depicts the plot of the 10 factor-level means of tank per device type. A peculiarity of the TOW sight was evidenced by the mean time to detection. It is the only device that did not display a difference in mean detection times between tank targets as did the other sighting devices.

4. An ANOVA on acquisition times resulted in the significance of device type and the interaction effect. Figure 31 displays the eight factor-level means of tank per device type. The mean acquisition times for both tank targets were less than or equal to 2 seconds for each of the devices, except for the NVD(RR). For some unknown reason, the observers required more time to acquire the PP tank with this NVD.

(c) Group 8 - light vegetation/rolling terrain; 2 kilometers maximum range. Test trials from group 4 test site V were included in this group because they were conducted under the same experiment factors. (See table 13 for the matrix of test trials.)

1. The CAM tank was detected by the observers at significantly shorter observer-to-target ranges than the PP tank. Apparently, the observers were able to overcome to a certain degree the limited visibility of the nighttime environment but not the effect due to camouflage. The effect of the applications was to blend the target into the background so as to require the observer to move closer to the target in order to detect it. This effect was also reflected in the fact that the CAM tank was detected first in 31 percent of the test trials with a median time to detection of 7.5 minutes. The PP tank detection time data were determined to be best described as normal with a mean and standard deviation of 9.9 and 5.9 minutes, respectively (less than the PP data). It is not known what caused this anomaly in detection times. (Figures 32 and 33 depict the CDF of the range and time data, respectively.)

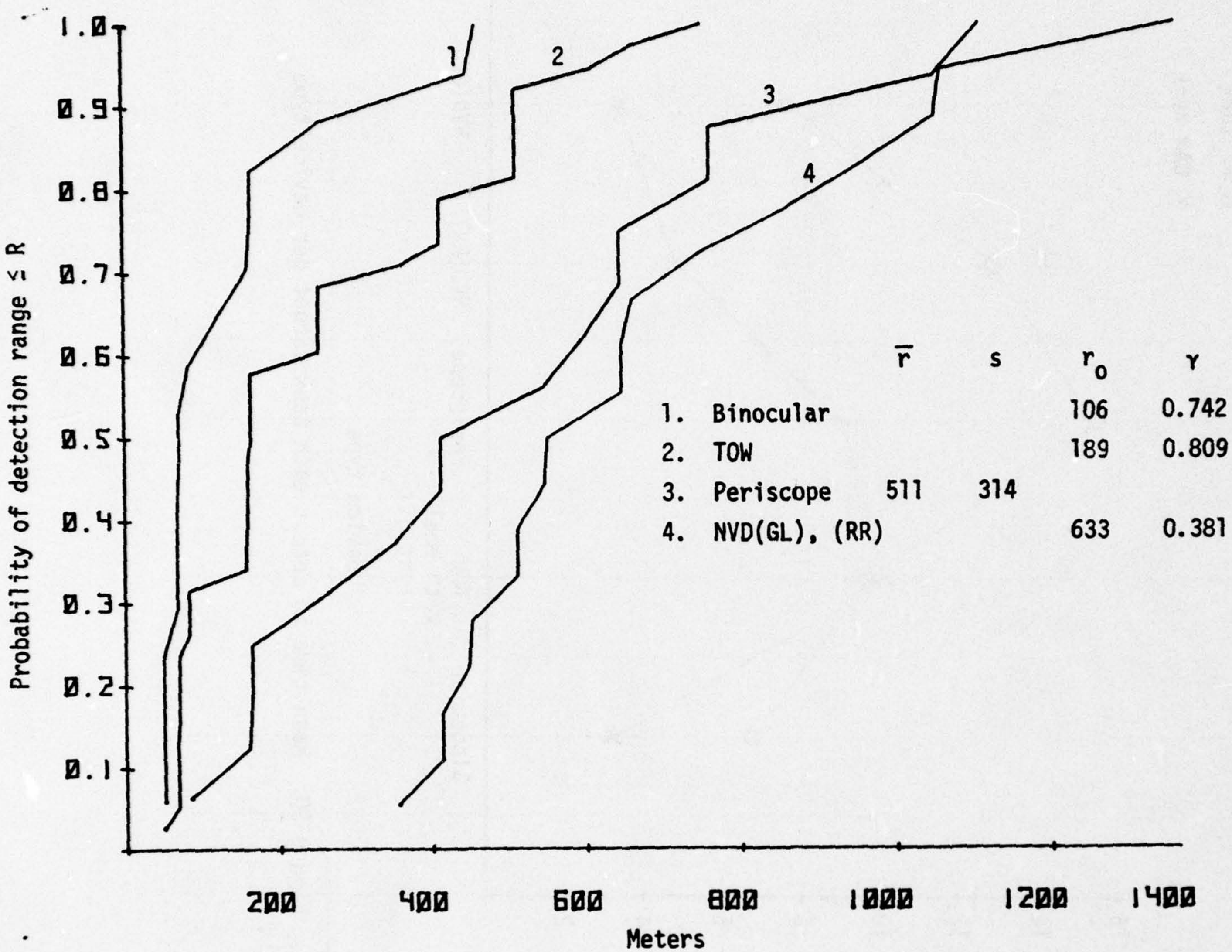

Figure 29. Cumulative distribution of detection range per device type, group 6 data

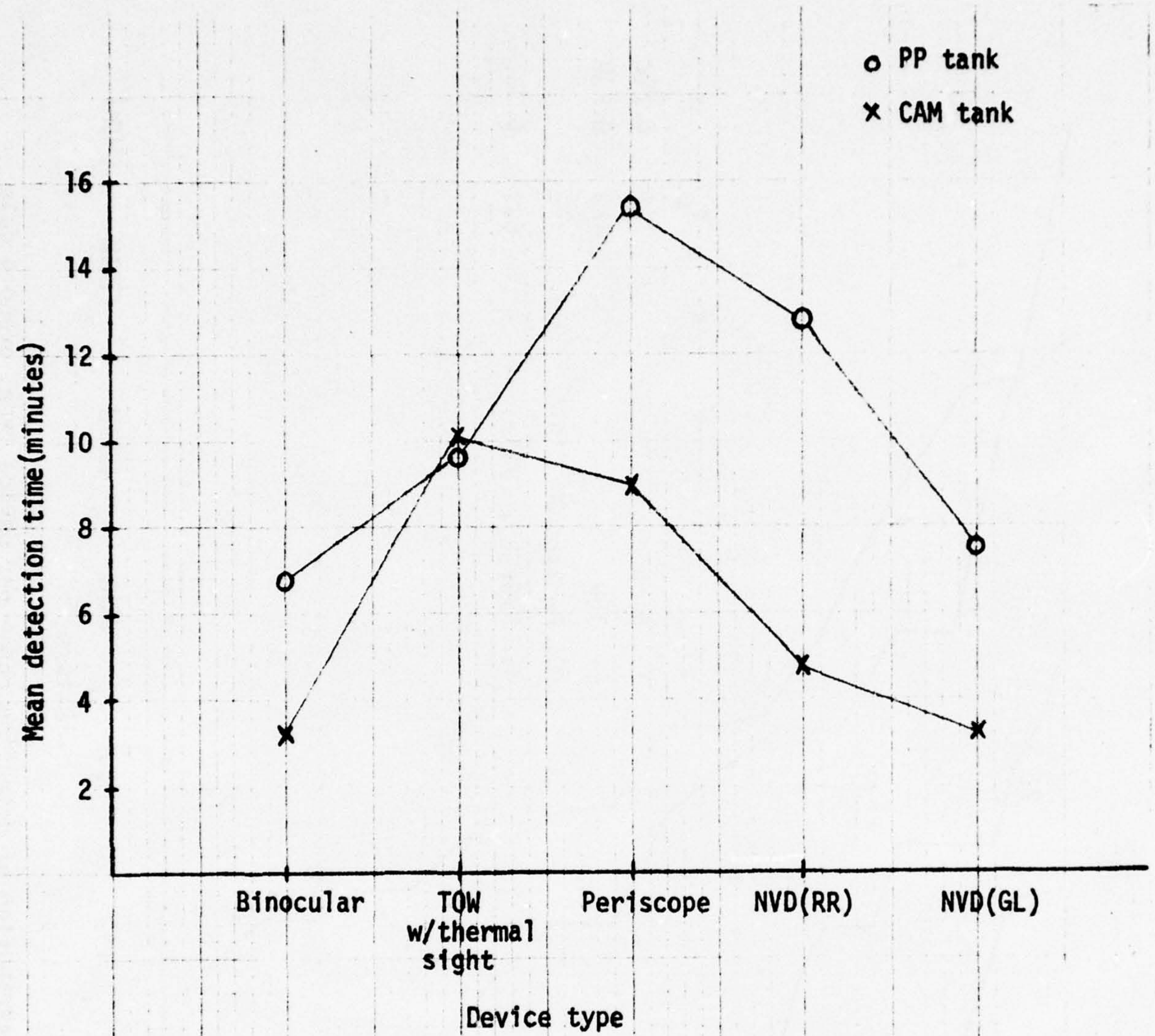

Figure 30. Mean time to detect each tank target per device type

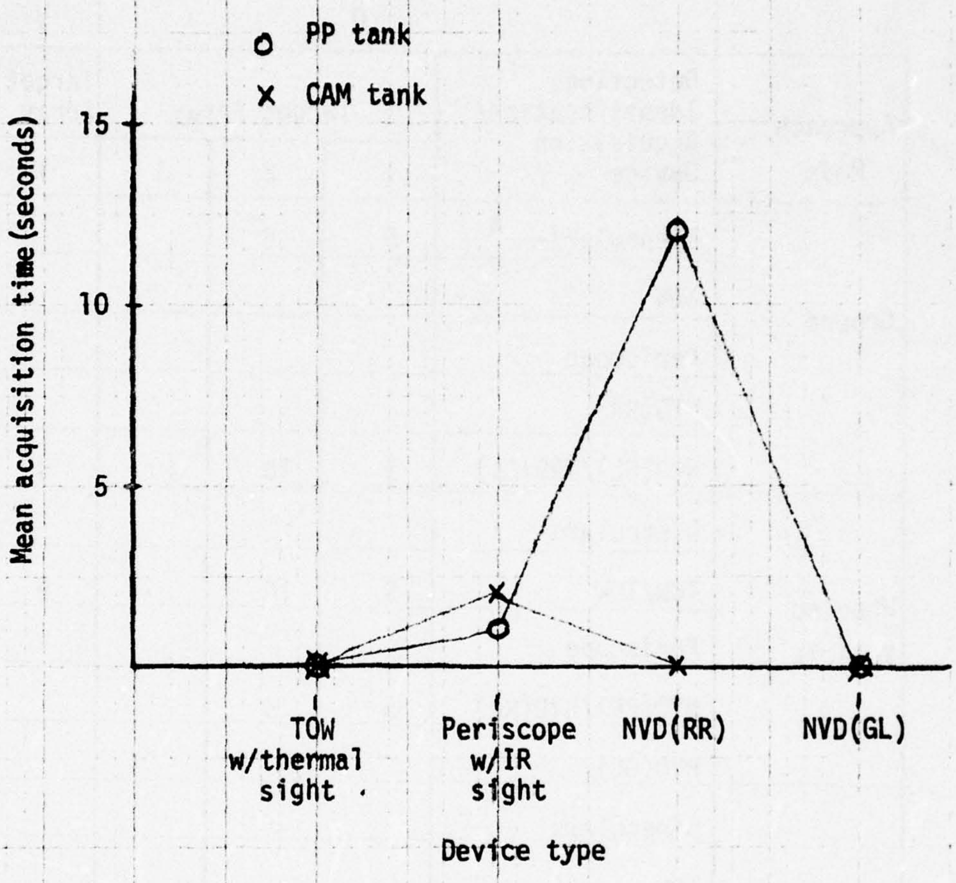

Figure 31. Mean time to acquire each tank target per device type

Table 13. Matrix of group 8 night trials - static target mode; light vegetation/rolling terrain conditions; 2 kilometers maximum range

		Test Site			
		U			V
Approach Mode	Detection, Identification/Acquisition Device	Target Array			Target Array
		1	2	3	1
Ground	Binocular/---[a]	5	5[c]		
	TOW				
	Periscope				
	NVD(RR)				
	NVD(GL)/NVD(GL)	5	10		9
Wheeled Vehicle	Binoculars				
	TOW/TOW	5	10		9
	Periscope				
	NVD(RR)/NVD(RR)	5	5		
	NVD(GL)				
Tank	Binoculars				
	TOW				
	Peri./Peri; Tele[b]	5	10		9
	NVD(RR)				
	NVD(GL)				

[a] Acquisition was not performed for these trials.

[b] Acquisition by telescope was performed against target array 1 test site V only.

[c] Replications per cell.

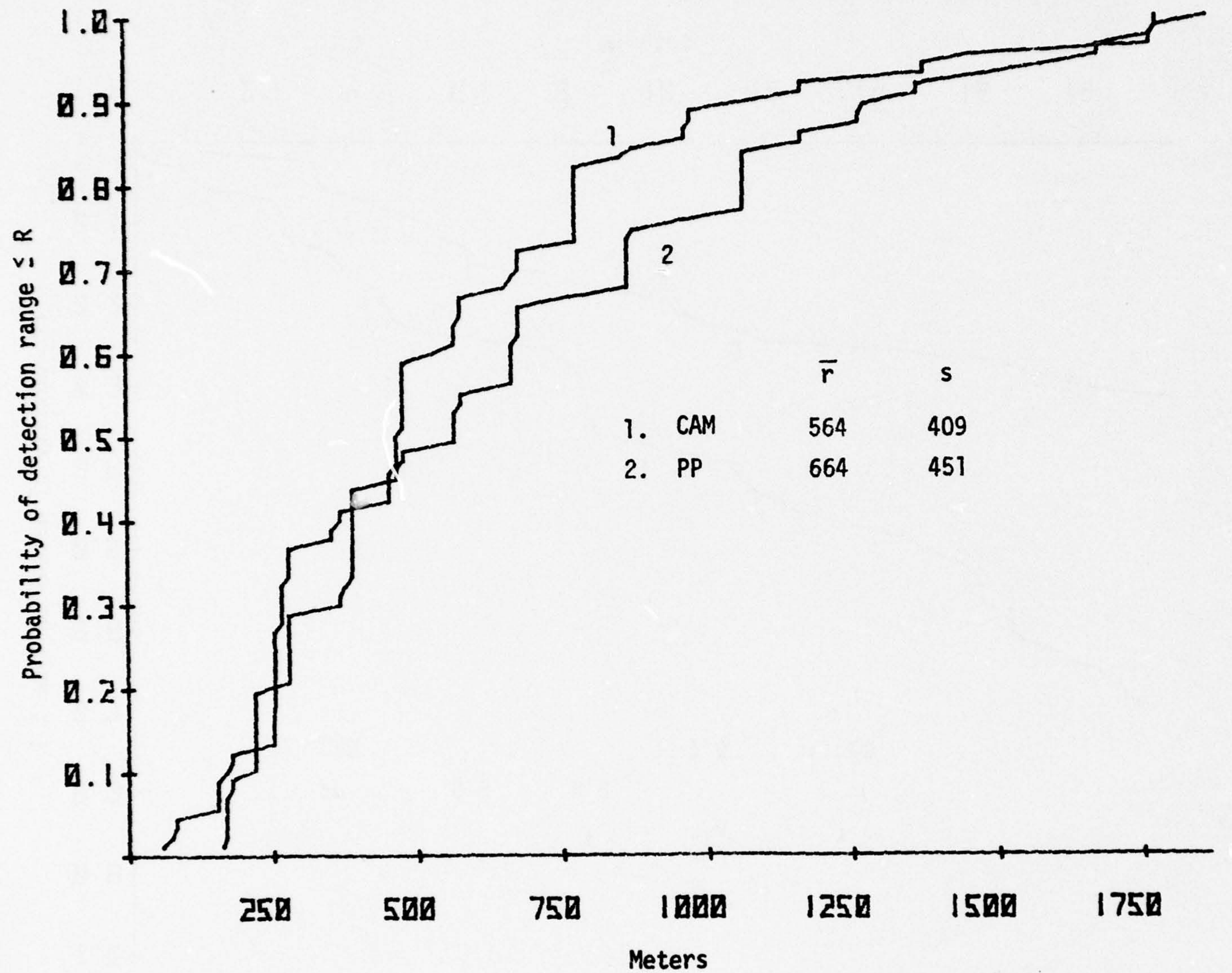

Figure 32. Cumulative distribution of detection ranges per tank target type, group 8 data

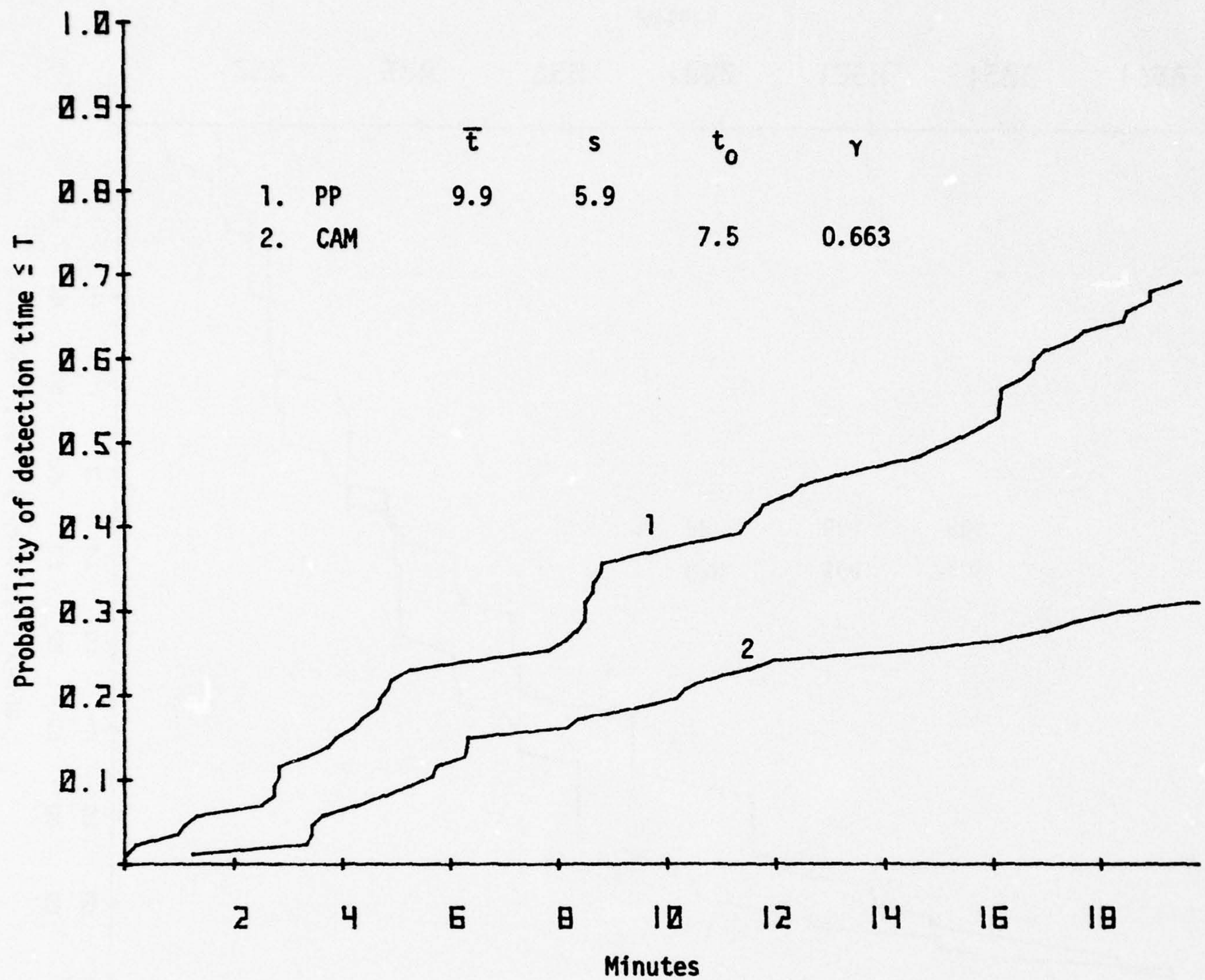

Figure 33. Cumulative distribution of time to first detection per tank target type, group 8 data

2. An ANOVA on detection ranges resulted in the significance of the main effects, tank and device type. Performing t-tests on the five levels of the factor device type identified a significant difference between the following three groups of devices: (1) binoculars, (2) TOW (with a thermal sight), and (3) infrared (IR) periscope and the night vision device (NVD) of the grenade launcher (GL) and recoilless rifle (RR). The observers using the TOW, with the thermal sight, were able to detect the tank targets at the longest observer-to-target ranges. The limitation of the narrow FOV of the TOW was apparently offset during these particular night trials by the thermal sight. As expected, the observers using binoculars were forced to move closer to the targets before they could detect them. Figure 34 depicts the CDF plots of these devices and the distribution parameters.

3. Performing an ANOVA on the times to detect the first target revealed the significance of the factor device type. Subsequent tests resulted in the significance between the night vision device (NVD) of the grenade launcher (GL) and the other devices: binoculars, TOW (with a thermal sight), IR periscope, and the NVD(RR). The NVD(GL) provided the observers a much more timely detection capability. The results of the analyses performed on the range and time data were not entirely consistent. Figure 35 depicts the CDFs of these data and the distribution parameters.

4. An ANOVA (tank x device) on acquisition times resulted in the significance of device type and the interaction effect. Figure 36 depicts a plot of the 10 factor-level acquisition means for each tank target per device type. As expected, the TOW with a thermal sight, NVD(RR), and NVD(GL) afforded the observers the best acquisition capability. However, the observers using an IR periscope could not acquire the tank targets in as timely a manner as when a day telescope was used. This anomaly may be due to the paucity of the detection data for the telescope and periscope devices.

(4) Night/moving target mode trials. Group 7 - heavy vegetation/rolling terrain; 1 kilometer maximum range. (See table 14 for the matrix of test trials.)

(a) The CAM detection ranges were determined not to be significantly less than the PP range data. This finding is probably the direct result of a combination of the effects produced by the nighttime environment and the movement cue (i.e., dust and noise) phenomenon, which affected the detection capability of the observers. This combination of effects overshadowed the effect due to the camouflage applications. Figures 37 and 38 depict the CDF and distribution parameters of the range and time data, respectively.

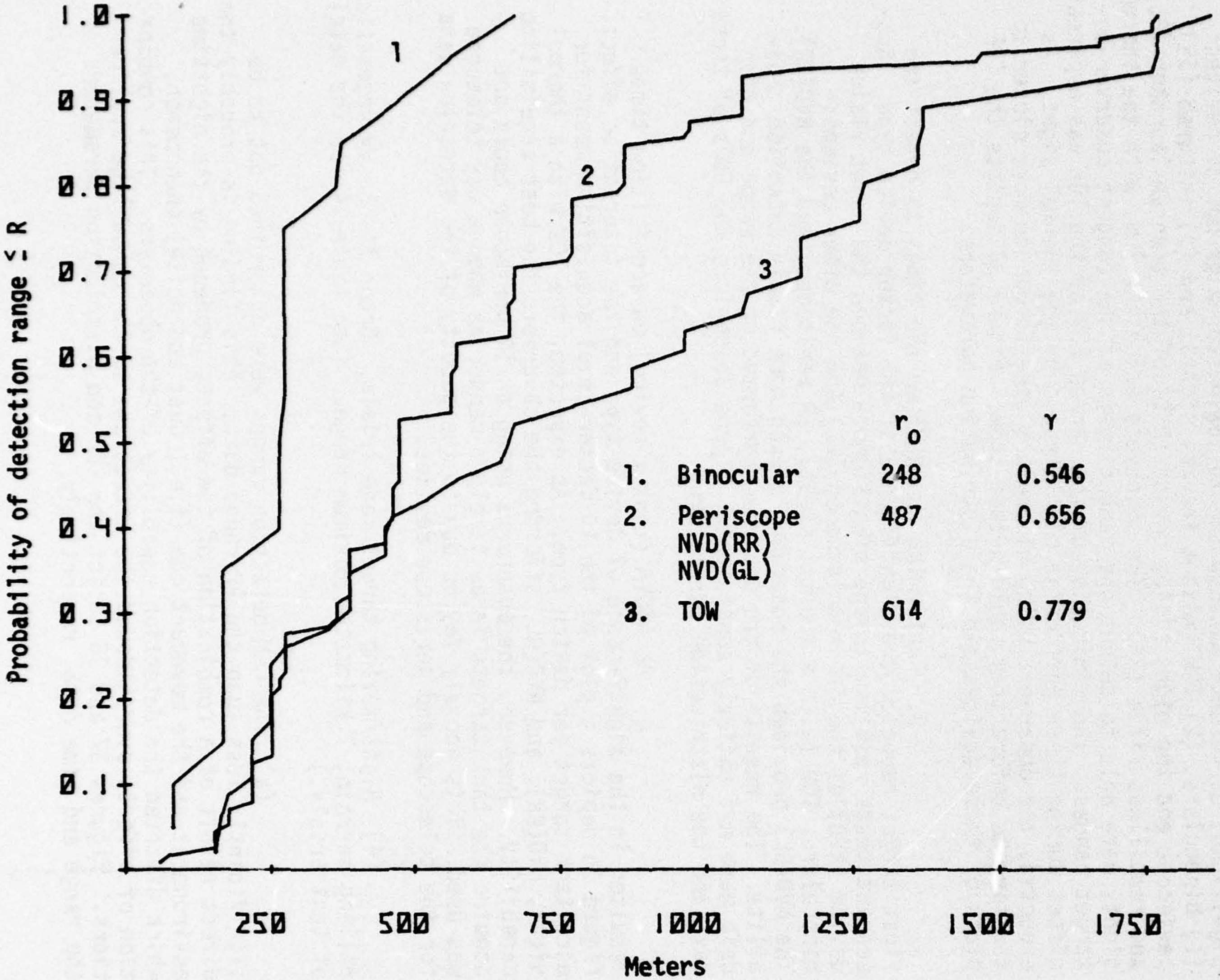

Figure 34. Cumulative distribution of detection range per device type, group 8 data

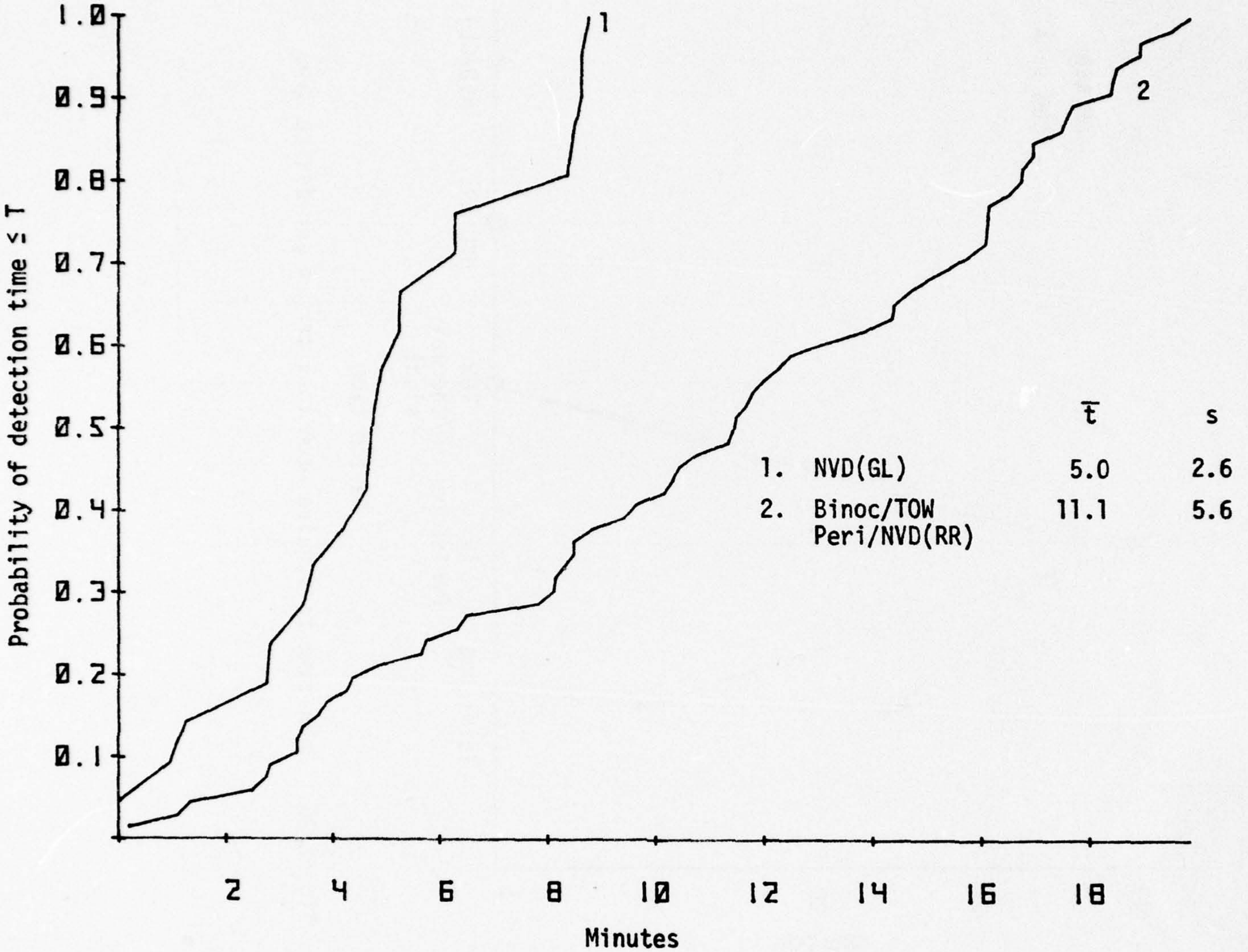

Figure 35. Cumulative distribution of time to first detection per device type, group 8 data

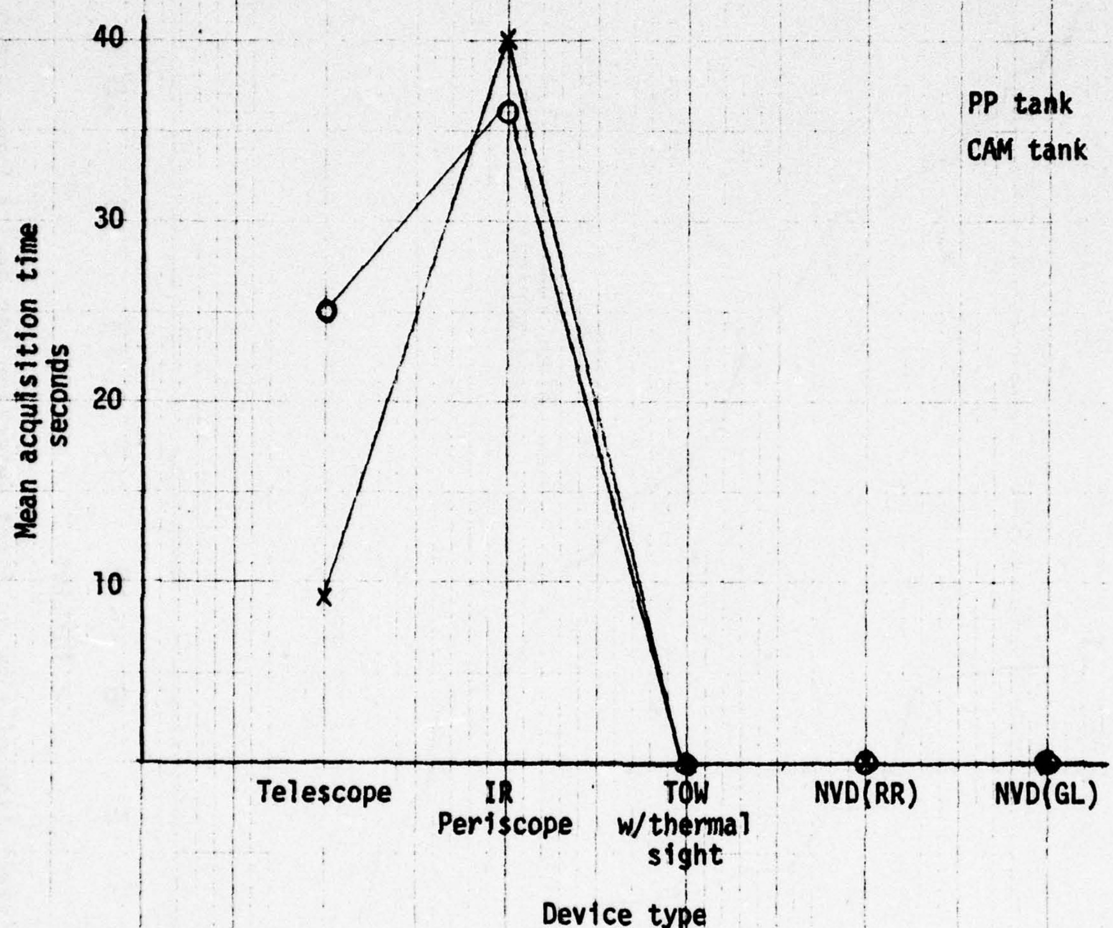

Figure 36. Mean time to acquire each tank target per device type

Table 14. Matrix of group 7 night trials - dynamic target mode; heavy vegetation/rolling terrain conditions; 1 kilometer maximum range

		Test Site	
		W	
Approach Mode	Detection, Identification/ Acquisition Device	Target Array	
		1	2
Ground	Binocular/---[a]	5[b]	5
	TOW		
	Periscope		
	NVD(RR)		
	NVD(GL)/NVD(GL)	5	5
Wheeled Vehicle	Binocular		
	TOW/TOW	5	5
	Periscope		
	NVD(RR)/NVD(RR)	5	5
	NVD(GL)		
Tank	Binoculars		
	TOW		
	Periscope/Peri.	5	5
	NVD(RR)		
	NVD(GL)		

[a] Acquisition was not performed for these trials.

[b] Replications per cell.

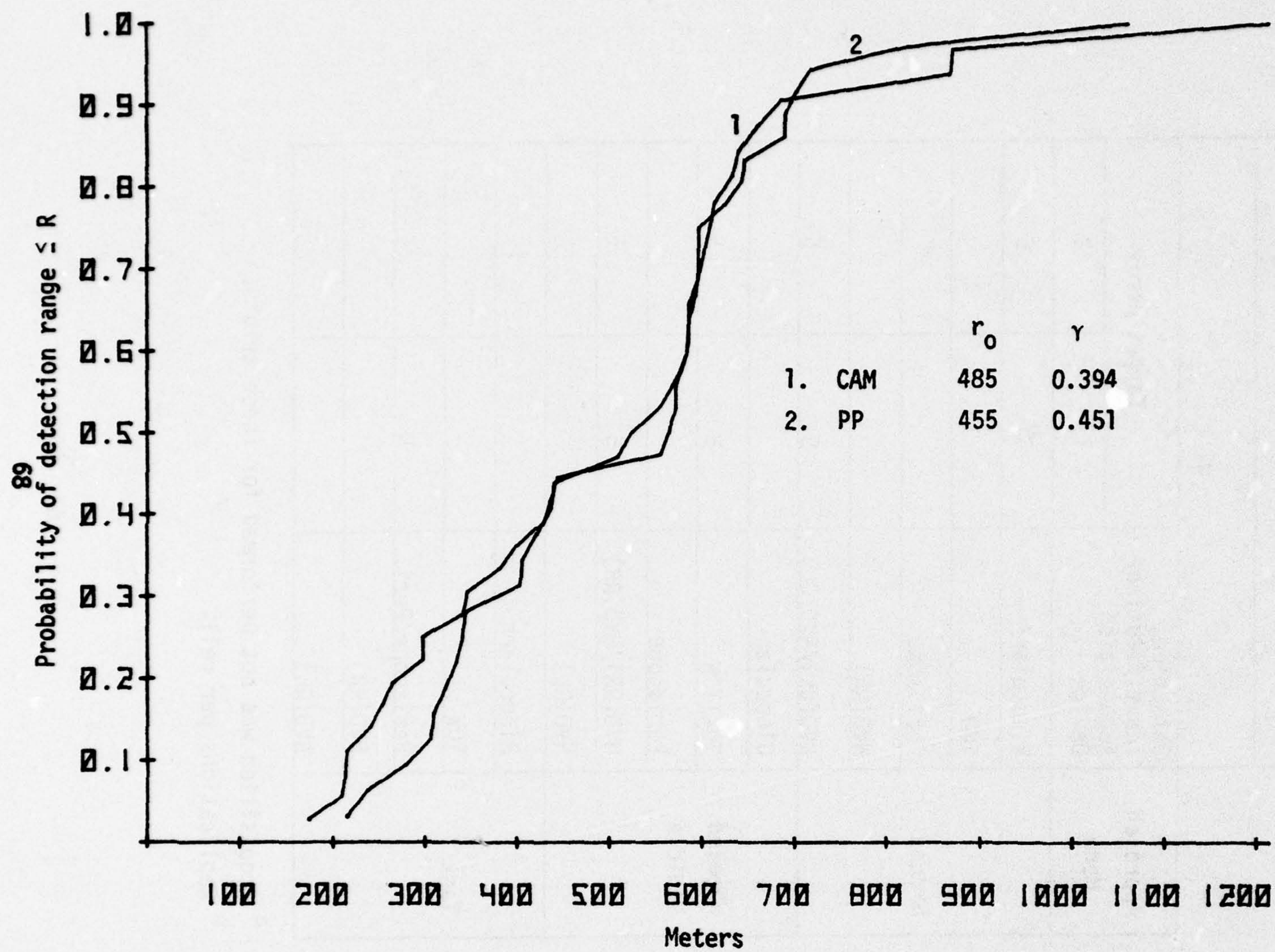

Figure 37. Cumulative distribution of detection range per tank target type, group 7 data

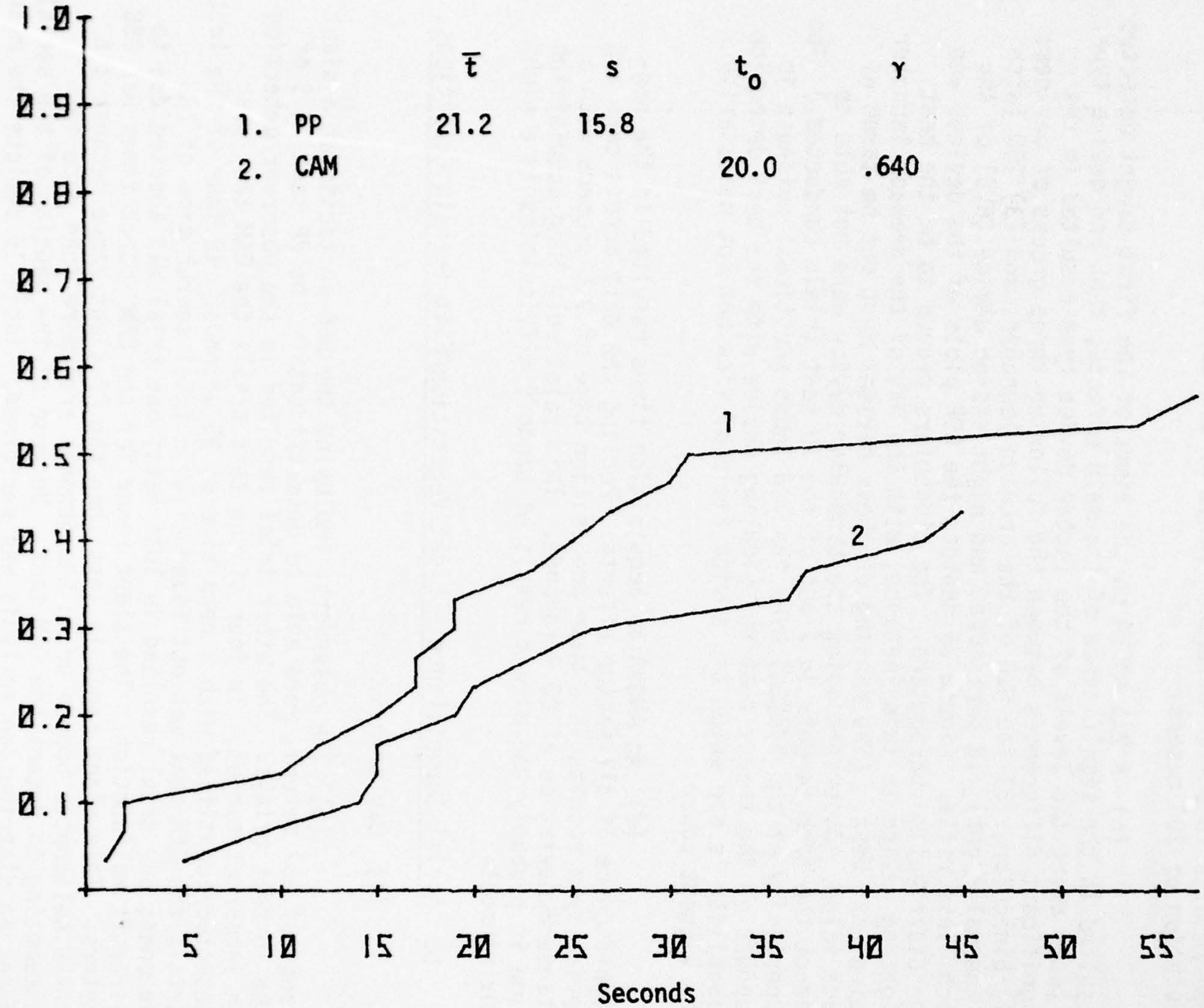

Figure 38. Cumulative distribution of time to first detection per tank target type, group 7 data

(b) An ANOVA on detection ranges resulted in the non-significance of all effects. Pooling the data across device and tank type results in a mean detection range of 510 meters with a standard deviation of 204 meters.

(c) A 2x5 ANOVA on the times of the first target detected resulted in the significance of the main effects, tank and device type. T-tests among the levels of the factor device type resulted in the significant differences between the following three groups of devices: (1) binocular, (2) the NVD of the grenade launcher, and (3) TOW (with a thermal sight), IR periscope, and night vision device (NVD) of the recoilless rifle. Figure 39 depicts the CDF plots of the devices and the distribution parameters. The binoculars proved to be the best sighting device in this instance, with the NVD of the grenade launcher being next best. (The ranking of these devices must not be taken at face value. Observers using the binocular device were not able to detect the tank targets in 7 out of the 10 test trials conducted.) The superiority of the NVD(GL) over the TOW lends additional evidence in support of the theory that the sighting device with the best detection capability is one which has a wide field of view but not necessarily the highest power.

(d) An ANOVA on acquisition times resulted in the non-significance of all factor effects. Pooling the data across tank and device type results in a mean acquisition time of 9.6 seconds with a standard deviation of 20.9 seconds. This relatively long acquisition time is probably the direct result of handoff difficulties in a night environment.

b. <u>Aerial Surveillance - Light Vegetation/Flat Terrain Conditions</u>.

(1) Day trials.

(a) The observers, employing the pop-up tactic at a slant range of 867 meters, were able to detect/identify the PP tank in 9 of the 10 test trials. The other trial resulted in the observer detecting an incorrect target. In four of the test trials the CAM tank was detected/identified with a mean time of 95 seconds. In four of the test trials the CAM tank was not found after a total search time of 180 seconds; one trial resulted in lost data; one trial was aborted due to aircraft malfunction. The slant range for the CAM search times was 858 meters. This slant range is less than the PP slant range because the OH-58 helicopter popped up in the general area more than once in attempting to detect the CAM tank. Because of the paucity of the aerial data, no distribution analysis was performed. Table 15 depicts the means and standard deviations of the data.

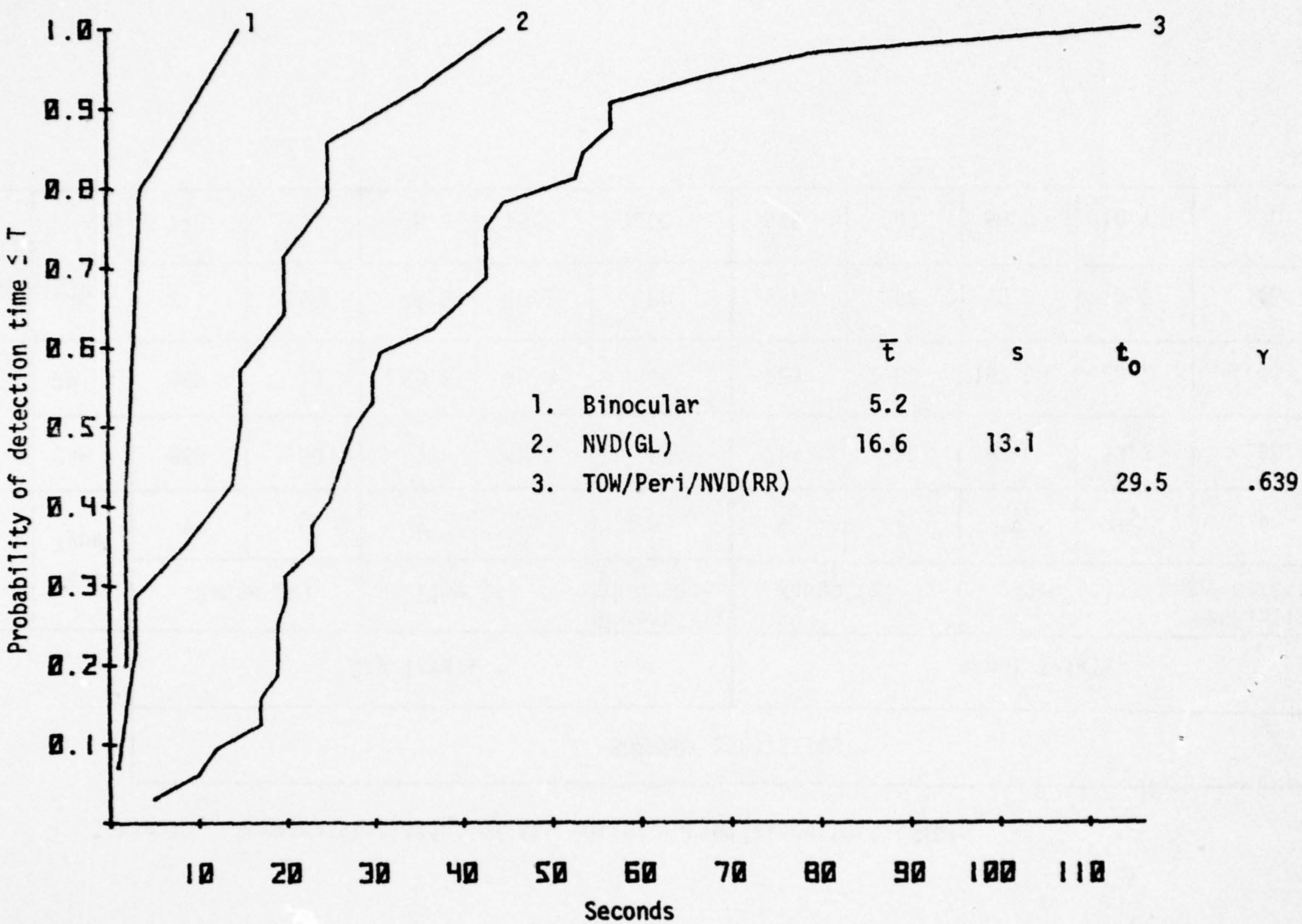

Figure 39. Cumulative distribution of time to first detection per device type, group 7 data

Table 15. Summary statistics of the aerial surveillance test trials

Tactic	Tank Type	SUMMARY STATISTICS									
		Day Trials					Night Trials				
		Range (m)		Time (s)		Probability of detection	Range (m)		Time (s)		Probability of detection
		$\overline{X}$	S	$\overline{X}$	X	P	$\overline{X}$	S	$\overline{X}$	S	P
Pop-up	CAM	858	.50	95	45.3	.50	721	.50	67.0	53.7	.20
	PP	867	.73	50.8	42.3	1.00	723	2.80	102.5	28.7	.40
Route Reconnisance	CAM	319	162	74.5	10.2	.80	557	292	62.8	10.2	.40
	PP	710	337	38.3	15.2	1.00	515	309	58.9	10.1	.30

(b) The route reconnaissance tactic resulted in quicker detection/identification times than the pop-up tactic; however, the slant ranges were less than the slant ranges for the pop-up tactic. All test trials resulted in the detection of the PP tank; the CAM tank was detected in 8 of the 10 trials (the observers could not find the CAM tank in the other two trials). The CAM tank ranges (times) were determined significantly less (greater) than those of the PP tank. (See table 15.)

(2) Night trials. In both the pop-up and route reconnaissance (RR) test trials, the observers were not able to find either tank target in at least six of the 10 test trials. The search times for the RR trials resulted in quicker detection/identification times; however, this result is offset by the fact that the slant ranges were less for the RR trials.

5. CONCLUSIONS.

a. The camouflage applications were only effective in the day/stationary target mode trials of the ground and aerial surveillance test. In these test trials the effect of camouflage applications on the observers resulted in a decrease in the probability of detection and an increase (decrease) in the time to detection (in the range of detection) of the camouflaged tank. The identification/acquisition of the camouflaged tank by the observers was less timely than the identification/acquisition time of the pattern-painted tank.

b. The sighting devices that possessed a wide field of view and a significant increase in magnification above that of the unaided eye afforded the observers a timely detection capability at the longest observer-to-target ranges.

c. The TOW sight, with its high power/narrow field of view, afforded the observers the most timely acquisition capability during the stationary target mode trials. Observers using the periscope device, with its lower power/wider field of view, were better able to acquire the moving tank targets.

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APPENDIX A

This appendix describes the distribution form of the lognormal distribution used in this test report.

a. The form of the lognormal probability density function used in this report is as follows:

$$f(y) = \frac{1}{\sqrt{2\pi}\,\sigma_y} e^{-\left\{\frac{(y-\mu_y)^2}{2\sigma_y^2}\right\}},$$

where $y = \log_e x$.

b. The calculated median (y_0) is defined as e^{μ_y} where:

$$\mu_y = \frac{\sum \log_e x}{n}$$

c. Gamma (γ) is defined as $\sqrt{\sigma_y^2}$ where $\sigma_y^2 = \frac{\sum (y-\mu_y)^2}{n-1}$.

APPENDIX B

The following tables illustrate the results of distribution analysis performed on the time data of tank target vehicles that were detected first for each of the test sites. A Kolmogorov-Smirnov one-sample test was used to determine the distribution form of the data.

Table B-1. Distribution parameters of group 1 acquisition data based upon first tank target detected

Observer event	Tank type	Distribution Parameters								Probability of first detection
		Range (meters)				Time (minutes)				
		Normal		Lognormal		Normal		Lognormal		
		Mean	Standard deviation	Median	Gamma	Mean	Standard deviation	Median	Gamma	
Detection	cam			1654	.387	8.0	5.2			.22
	PP			2166	.214	9.6	4.8			.78
Identification	cam			1508	.432	10.4	6.7			
	PP			2123	.217	10.9	4.4			
Acquisition	cam			1495	.440	10.8	6.4			
	PP			2101	.230	11.2	4.5			

Table B-2. Distribution parameters of group 2 acquisition data based upon first tank target detected

Observer event	Tank type	Distribution Parameters								Probability of first detection
		Range (meters)				Time (seconds)				
		Normal		Lognormal		Normal		Lognormal		
		Mean	Standard deviation	Median	Gamma	Mean	Standard deviation	Median	Gamma	
Detection	cam			1609	.157			10.9	.839	.51
	PP			1592	.144			10.5	.751	.49
Identification	cam			1590	.149			15.5	.906	
	PP			1560	.135			13.5	.795	
Acquisition	cam			1579	.153			24.1	.697	
	PP			1551	.134			21.7	.680	

Table B-3. Distribution parameters of group 3 acquisition data based upon first tank target detected

Observer event	Tank type	Distribution Parameters								Probability of first detection
		Range (meters)				Time (minutes)				
		Normal		Lognormal		Normal		Lognormal		
		Mean	Standard deviation	Median	Gamma	Mean	Standard deviation	Median	Gamma	
Detection	cam	1239	492			7.9	5.8			.21
	PP			1684	.289			2.1	1.450	.79
Identification	cam	1144	455			10.4	5.9			
	PP			1614	.325			3.1	1.219	
Acquisition	cam	1142	492			10.9	5.8			
	PP			1606	.332			3.5	1.105	

Table B-4. Distribution parameters of group 4 acquisition data based upon first tank target detected

Observer event	Tank type	Distribution Parameters: Range (meters), Normal: Mean	Range (meters), Normal: Standard deviation	Range (meters), Lognormal: Median	Range (meters), Lognormal: Gamma	Time (minutes), Normal: Mean	Time (minutes), Normal: Standard deviation	Time (minutes), Lognormal: Median	Time (minutes), Lognormal: Gamma	Probability of first detection
Detection	cam			457	.818	14.5*				.05
	PP			498	.954			8.7	.533	.95
Identification	cam	465*				14.8*				
	PP	475	325			11.4	4.0			
Acquisition	cam	465*				15.8*				
	PP			316	.919	11.7	4.2			

* This data was determined to be exponential.

Table B-5. Distribution parameters of group 5 acquisition data based upon first tank target detected

Observer event	Tank type	Distribution Parameters								Probability of first detection
		Range (meters)				Time (seconds)				
		Normal		Lognormal		Normal		Lognormal		
		Mean	Standard deviation	Median	Gamma	Mean	Standard deviation	Median	Gamma	
Detection	cam	1917	57					11.8	.833	.50
	PP	1920	55					8.9	1.026	.50
Identification	cam	1884	73			24.0	14.9			
	PP	1895	76			22.6	17.0			
Acquisition	cam	1862	79					26.6	.670	
	PP	1875	76					22.5	.853	

Table B-6. Distribution parameters of group 6 acquisition data based upon first tank target detected

Observer event	Tank type	Range (meters) Normal Mean	Range (meters) Normal Standard deviation	Range (meters) Lognormal Median	Range (meters) Lognormal Gamma	Time (minutes) Normal Mean	Time (minutes) Normal Standard deviation	Time (minutes) Lognormal Median	Time (minutes) Lognormal Gamma	Probability of first detection
Detection	cam	297*						5.7	.683	.52
	PP	364	243			11.4	3.9			.48
Identification	cam	188*						8.0	.669	
	PP			193	.740	12.5	4.0			
Acquisition	cam	163*						8.0	.669	
	PP			193	.740	11.9	3.6			

* This data was determined to be exponential.

Table B-7. Distribution parameters of group 7 acquisition data based upon first tank target detected

		Distribution Parameters								
		Range (meters)				Time (seconds)				Probability of first detection
Observer event	Tank type	Normal		Lognormal		Normal		Lognormal		
		Mean	Standard deviation	Median	Gamma	Mean	Standard deviation	Median	Gamma	
Detection	cam			485	.409			20.5	.662	.44
	PP	499	208					18.3	.938	.56
Identification	cam			462	.500			51.0	.659	
	PP	492	231					68.2	.510	
Acquisition	cam			488	.471			56.9	.730	
	PP	519	224					74.1	.496	

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Table B-8. Distribution parameters of group 8 acquisition data based upon the first tank target detected

Observer event	Tank type	Range (meters) Normal Mean	Range (meters) Normal Standard deviation	Range (meters) Lognormal Median	Range (meters) Lognormal Gamma	Time (minutes) Normal Mean	Time (minutes) Normal Standard deviation	Time (minutes) Lognormal Median	Time (minutes) Lognormal Gamma	Probability of first detection
Detection	cam			471	.709			7.1	.698	.27
	PP			581	.678	10.2	6.2			.73
Identification	cam			349	.689			9.5	.576	
	PP			492	.658	11.8	6.0			
Acquisition	cam			372	.642			9.6	1.105	
	PP			522	.665	11.3	6.0			

Table B-9. Distribution parameters of groups 10 and 12 acquisition range data

Observer event	Tank type	Distribution Parameters								Tank Type
		Group 10 Range (meters)				Group 12 Range (meters)				
		Normal		Lognormal		Normal		Lognormal		
		Mean	Standard deviation	Median	Gamma	Mean	Standard deviation	Median	Gamma	
Detection	cam	1329	528					968	.268	OD
	PP	1438	441			1054	352			PP
Identification	cam	1246	603					938	.269	OD
	PP	1209	305			1023	341			PP
Acquisition	cam	1246	603					938	.269	OD
	PP	1214	315			1018	343			PP